DIVISION OF AGRICULTURAL SCIENCES
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Integrated Management of Ground and Surface Water In Relation To Water Importation

The Experience of Los Angeles County

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by

Robert L. Leonard[1/]

INTRODUCTION

Serious economic and institutional problems associated with the utilization of groundwater in California were revealed in 1950 in a study by the Giannini Foundation.[2/] A series of regional studies was suggested, each of which could examine the "interrelations between the groundwater resources of an area and the economic and social framework resulting from and, in turn, conditioning their use."[3/] A study of the economic and institutional problems of groundwater management in a particular area naturally centers on the basic problem or problems of that area. Hence, the regional study is in a sense a topical study which draws on the experience of a specific area.

The first regional study was of Antelope Valley and focused on the economic and social problems of mining groundwater in an arid and hydrologically self-contained basin.[4/] In the Antelope Valley, "a small flow resource (recharge), which is highly variable over time, has created a large, dependable, and easily accessible stock resource (volume of groundwater in storage) which can serve as the basis for flourishing agricultural and urban development--for a limited and

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1/ Formerly Junior Specialist, Agricultural Experiment Station, University of California, Berkeley. Since 1963, Assistant Professor of Agricultural Economics, University of Connecticut, Storrs.

2/ Patricia McBride Bartz, Ground Water in California: The Present State of Our Knowledge (with a foreword by S. V. Ciriacy-Wantrup), University of California, Giannini Foundation Ground Water Studies No. 1 (Berkeley, 1950), 67p.

3/ Ibid., p. 67.

4/ J. Herbert Snyder, Ground Water in California: The Experience of Antelope Valley (with a foreword by S. V. Ciriacy-Wantrup), University of California, Giannini Foundation Ground Water Studies No. 2 (Berkeley, 1955), 171p.

foreseeable period of time."[1/] The slow rate at which the basin is recharged and the high costs of importing water to the valley indicate that the falling water level will eventually force a shift out of agriculture. Since urban uses can support the costs of importing, "urbanization may soften the harshness of such a transfer and also act to subsidize the importation of water to the area."[2/]

The second regional study was of Santa Clara County and focused on their experience in integrating the management of ground and surface water through the organizational structure of the public district.[3/] Utilization of surface water was limited by the seasonal and cyclical patterns of precipitation. Surface reservoirs could be used successfully to smooth out fluctuations within seasons but not between seasons, as several dry years often come in succession. Groundwater, being more dependable, was preferred and was developed in excess of the rate of replenishment, while a considerable portion of the local runoff was wasting to the sea. The continued overdraft was not only depleting the original stock of water but also causing soil compaction and seawater intrusion which were destroying the underground reservoir. Individuals thought of a variety of solutions, but each necessitated collective action. "The ability to take such action required the formation of an organization with a structure which would relate the interested individuals to each other and to the resource problem."[4/] Through the organizational structure of the public district, collective action is being taken to capture flood waters for replenishing the groundwater basins.

In some areas of California, the growing demand for water has changed the role of groundwater basins from that of a single source to that of a supplemental source and reservoir for terminal storage of imported water. The effective utilization of a groundwater basin in conjunction with an imported supply is possible only if there is a decision-making structure capable of coordinating

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1/ Ibid., p. viii. For additional discussion of stock and flow resources, see S. V. Ciriacy-Wantrup, Resource Conservation, Economics, and Policies (Berkeley: University of California Press, 1952), pp. 27-47.

2/ Snyder, op. cit., p. 149.

3/ Stephen C. Smith, The Public District in Integrating Ground and Surface Water Management: A Case Study in Santa Clara County, University of California, Giannini Foundation Research Report No. 252 (Berkeley, 1962), 135p.

4/ Ibid., p. 2.

many interdependent interests. The basic problems appear to be those associated with modifying organizational structures to accommodate the changing role of groundwater basins in supplying the increasing demands for water.

This study will concentrate on the groundwater problems of the coastal region of Los Angeles County, including the San Fernando and San Gabriel Valleys as well as the coastal plain (Figure 1). The experience of other areas will be brought in for comparative purposes in a later section where alternative organizational structures and management plans are discussed.[1/] There will be an attempt to clarify the management issues and alternatives in Los Angeles County and to assist other areas contracting for imported supplies in utilizing the experience of Los Angeles County.

The Necessity of Group Action

Groundwater basins in Los Angeles County have been seriously overdrawn, and valuable underground storage space is being destroyed by seawater intrusion (Figure 2). The Metropolitan Water District of Southern California has had installed facilities with sufficient capacity to have imported enough additional Colorado River water to have prevented this overdraft.

Due to increasing demands for current use, the Colorado River Aqueduct no longer has sufficient capacity to make up the accumulated overdraft. Keeping the basins full through greater utilization of the Colorado River Aqueduct would have reduced the amount of water which will eventually have to be imported from northern California under the State Water Plan. Viewed either in terms of the variable costs to the Metropolitan Water District or in terms of the prices at which the District was selling water, keeping the basins full would have been relatively inexpensive compared to the costs of northern California water.

Increased imports would have been economical for the area as a whole, but the groundwater basins were shared by numerous pumpers. An individual pumper could do nothing to prevent the groundwater level from falling; his only course of action was to deepen his wells and continue pumping until the usable water was depleted or the increased pumping costs made continued extraction uneconomical.[2/]

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1/ Infra, pp. 41-55.

2/ For additional discussion on the management of fugitive resources, see Ciriacy-Wantrup, op. cit., pp. 141-149.

FIGURE 1: Location of Study Area

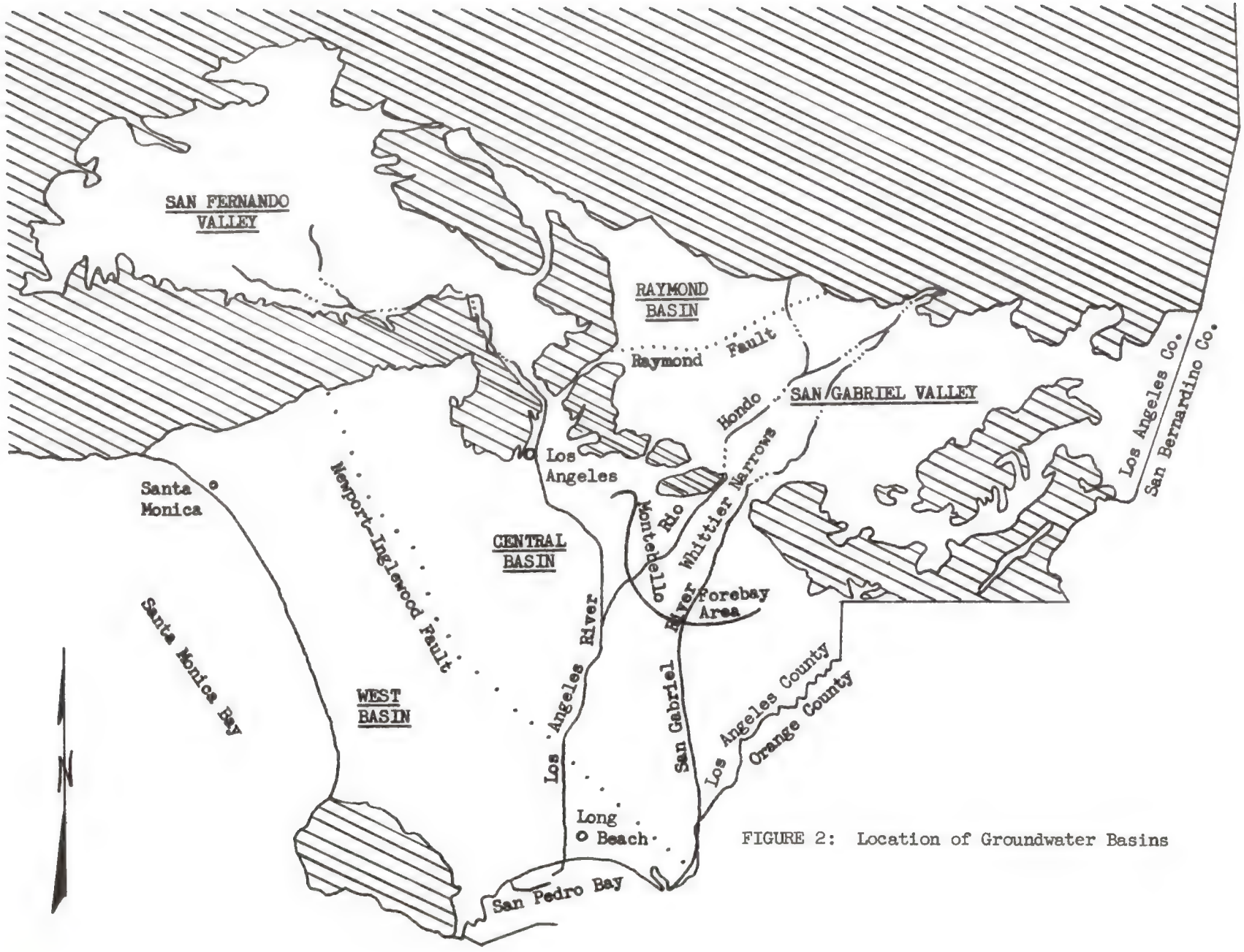

FIGURE 2: Location of Groundwater Basins

There has been progress toward the efficient utilization of local and imported water supplies only where the interests of individual pumpers have been coordinated. Groundwater rights have been adjudicated in some basins, and water rights exchange pools have been formed to avoid placing unnecessary hardships on those not having surface water connections. Group action, through the institutional framework of the public district, has been taken to purchase imported water for replenishing underground basins and to protect a portion of the coastal area from seawater intrusion with a line of injection wells which create a freshwater pressure mound.

Potential Role of Underground Reservoirs

A brief review of the climate, the seasonal variation in demand for water, and the economics of providing importation facilities reveals the importance of local storage in supplying the demand for water in Los Angeles County. As those familiar with southern California are well aware, demand for water is highest in summer; the only significant rainfall occurs in winter. Average annual precipitation is small and highly variable.[1/] Several dry years often come in succession. Groundwater basins have functioned as natural regulators. Flood-control activities and water-spreading programs of the Los Angeles County Flood Control District have enabled the collection and storage of local precipitation. Currently, less than 10 percent of local runoff reaches the ocean, this being the peak of large storms and drainage from the coastal areas below the spreading grounds.

To maintain a constant rate of flow for efficient utilization of water import facilities, seasonal peaks in demand must be met from either terminal storage or a supplemental source. In the Los Angeles area, standby pumps and wells are more economical for this purpose than surface storage.

The demand for water grows rather steadily through time, whereas importation facilities can be more economically constructed in large units. In addition to smoothing out fluctuations in local supply and in demand, the 4,000,000 acre-feet of usable underground storage in Los Angeles County is sufficient for

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1/ The average annual precipitation varies from approximately 11 inches along the coast to about 16 inches along the hills back of the coastal plain.

significant storage of water following an expansion in import facilities for use during the years preceding the next expansion.[1/] The underground reserve can be increased either by replenishing with imported water or by taking the imported water for current use and allowing natural recharge to accumulate.

The potential role of groundwater basins can be realized only if the management of ground and surface supplies are effectively integrated. Integrating management requires the elimination of the need to capture groundwater through use and the establishment of an organizational structure through which many interdependent activities can be coordinated.

The need to capture through use can be eliminated through collective control over extractions either by adjudicating rights or through economic incentives to individual users. The feasibility of economic control over pumping has been greatly increased by legislation making possible the assessment of groundwater extractions for the financing of replenishment activities.

Management of ground and surface water can be integrated only through an organizational structure capable of coordinating the conservation of local water, importation, replenishment, extractions, and distribution. Numerous public and private agencies are involved. An appropriate organizational structure is just as essential as collective control over extractions and may be as difficult to achieve.

Objectives and Procedure

The objectives of the study are to (1) identify the basic requirements for the effective utilization of ground and surface water resources, (2) evaluate alternative means of establishing collective control over groundwater extractions, and (3) evaluate alternative organizational structures for integrating the management of ground and surface water in relation to water importation.

The experience of Los Angeles County will be analyzed to determine the impediments to efficient management of water resources and to identify the conditions under which significant institutional innovations have been made to improve water management.

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1/ This estimate excludes storage below sea level in coastal basins and more than 200 feet below the ground surface in the inland basins. Statement by Herbert A. Howlett for California Department of Water Resources in California Legislature, Assembly Interim Committee on Water, Hearings, Ground Water Problems (H.R. 179) (Anaheim, 1961), p. 11.

This experience should be helpful in identifying the basic requirements for successful management. The potential role of groundwater basins in supplying future water needs will be analyzed. Alternative means of controlling draft and specific organizational structures for integrating management will be formulated. The proposals will be evaluated by determining their applicability to the solution of management problems in Los Angeles County.

AN OPPORTUNITY LOST

Groundwater basins in Los Angeles County have been seriously overdrawn. Vacant storage under the San Gabriel and San Fernando Valleys and the coastal plain of Los Angeles County totals approximately 2,500,000 acre-feet. Groundwater levels are below sea level in over 80 percent of a 460-square-mile area of the coastal plain. Consequently, valuable underground storage is being lost due to seawater intrusion.

According to estimates by the Metropolitan Water District, facilities were available to have delivered an additional 5,000,000 acre-feet of Colorado River water between 1941 and June 30, 1961.[1/] It will be shown below that the unused capacity was well distributed through time (rather than concentrated in a few wet years) and that the overdraft on groundwater basins could have been prevented through increased importation at relatively little cost.

No Physical Shortage

The designers of the Colorado River Aqueduct realized that the entire capacity of the proposed aqueduct would not be used for several years. Comparative estimates of construction costs were prepared for one-third-capacity, one-half-capacity, and two-thirds-capacity flows. For the three principal types of conduit (lined canals, covered conduit, and tunnels), the reduction in estimated costs was relatively small as the capacity was decreased. Estimates for half capacity ran from 80 to 85 percent of full capacity.[2/]

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1/ Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), p. 5.

2/ Idem, History and First Annual Report (Los Angeles, 1939), p. 105.

Cost estimates were checked by calling for bids on five major tunnels at full capacity and at half capacity. The bids substantiated the estimates, and no further consideration was given to the possibility of staging the construction of the principal conduits.

Where inverted siphons were long or had high heads, double-barreled construction would have been desirable even if full capacity had been needed immediately.[1/] Likewise, multiple-unit pumping plants were more practical to construct and operate. The initial construction included: one of an ultimate two barrels for siphons, three of an ultimate nine pumps at each of the five pumping plants, and one of an ultimate three transmission lines for delivering power to the pumping plants. Where practical, reservoirs along the aqueduct were originally built to only part of their final capacity.

Due to variability in the amount of outage time necessary for inspection, cleaning, and repairs, it is not possible to calculate the exact minimum average rate of delivery for a particular combination of installed facilities. To deliver an ultimate average flow of 1,500 cubic feet per second, the main aqueduct was designed at 1,605-cubic-feet-per-second capacity; and nine pumps were installed, each with a capacity of 200 cubic feet per second. It cannot be assumed that water could have been delivered continuously at a rate equal to the installed capacity as shown in Figure 3. On the other hand, allowances for silting make operation in excess of design capacity possible. The average flow during the operating year 1958-59 exceeded the design capacity of the single-barreled siphons by 25 cubic feet per second. The installed capacity in Figure 3 is the design capacity of the limiting feature in each year and gives a reasonable indication of the average rate at which water could have been delivered in that year.

Figure 3 supports the Metropolitan Water District's estimate that an additional 5,000,000 acre-feet could have been delivered between the beginning of operation in 1941 and June 30, 1961. If there had been a demand for water, deliveries could have been increased by far more than 5,000,000 acre-feet by adding units to the staged features at earlier dates. The capacities shown in Figure 3 refer only to limitations in the main aqueduct system. The distribution system and treatment plants were not considered as they were expanded in

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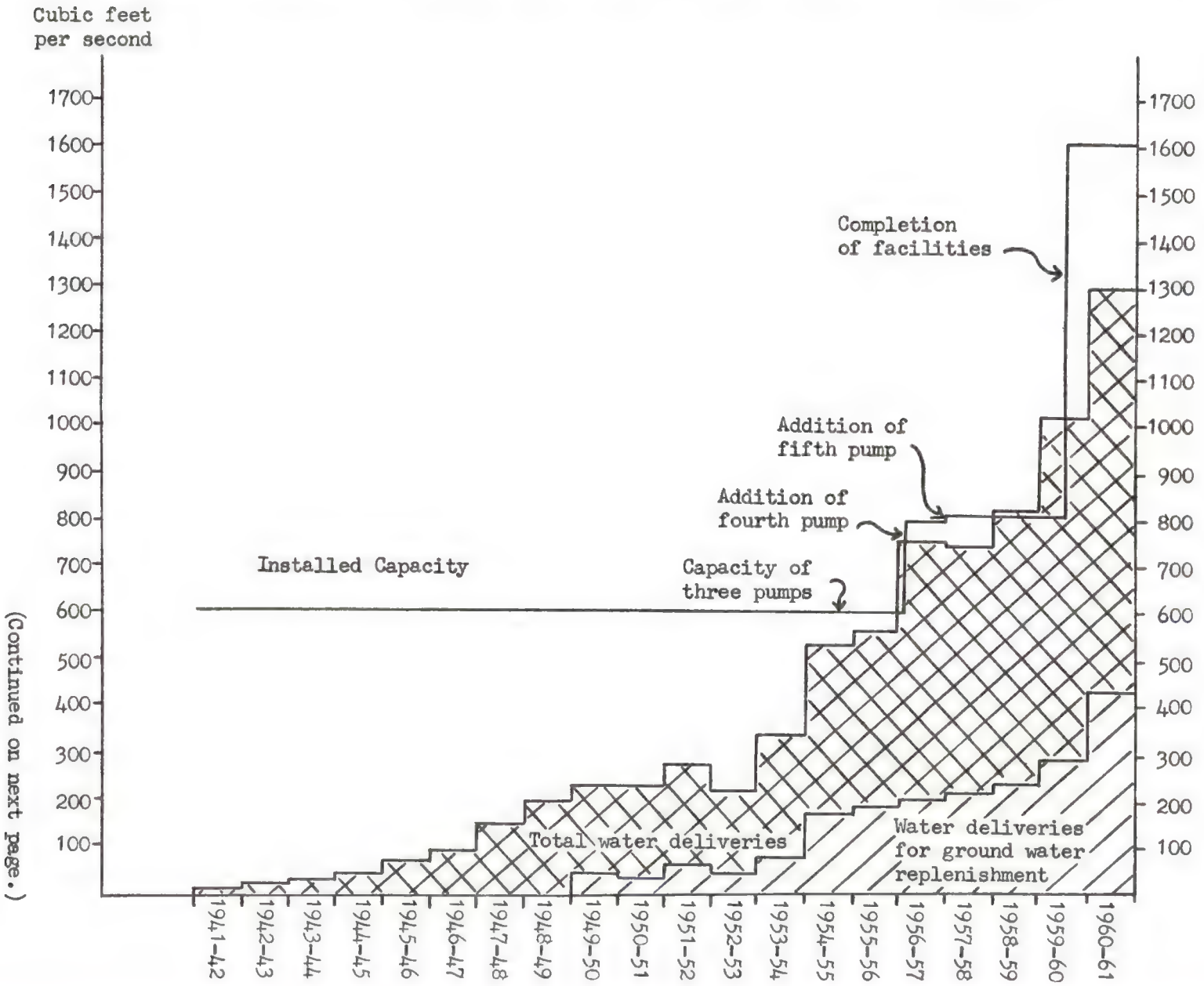
1/ Ibid., p. 105.

FIGURE 3: Installed Capacity and Annual Average Rate of Use of Colorado River Aqueduct[1/]



(Continued on next page.)

FIGURE 3--continued.

1/ Water deliveries for groundwater replenishment and total water deliveries are shown in terms of average cubic feet per second for each operating year.

Installed capacity:

Three pumps were originally installed with a total capacity of 600 cubic feet per second.

Pump 4 began operating August 16, 1956.

Pump 5 began operating May 1, 1957.

After pump 5 was installed, the installed capacity was limited to 805 cubic feet per second because only one barrel of each of 47 siphons had been installed.

In early 1960, facilities were completed for delivery of the full 1,605 cubic feet per second.

Source: Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), pp. 1-5 and 53.

accordance with growth in demand. Without question, sufficient physical facilities were available to stop the overdraft on groundwater basins and refill vacant storage.

A Chance to Fill the Basins at Relatively Small Cost

There is no way of determining exactly how much the Metropolitan Water District's costs would have been increased by additional imports. However, it may be possible to show that building up groundwater reserves would have been highly economical without knowing what the exact costs would have been. This can be done if we can establish that the costs would not have exceeded some level at which additional imports would have been clearly advantageous to the area.

Completed facilities were essentially the same from the beginning of operations in 1941 through the fiscal year 1954-55. During this time, both increases in intensity of use and a general rise in prices contributed to increases in operating expenses. The difference in annual operating expenses between a year of small deliveries and a later year of larger deliveries divided by the difference in quantity delivered overstates the addition to operating expenses caused by a one-unit increase in delivery because of rising prices. However, through such a calculation we can establish an upper limit to what the costs per unit would have been for making additional use of existing facilities. Since most of the increase in deliveries came after fiscal year 1946-47, we can reduce the effect of the rising price level by comparing 1946-47 to 1954-55 rather than comparing 1941-42 to 1954-55.

Since the overdraft could have been stopped and the groundwater reserves built up either by increased surface delivery and reduced pumping or by groundwater replenishment with imported water, we must consider the costs of both methods. As Colorado River water is filtered and softened before delivery for municipal use, these costs must be included in the analysis. In the case of groundwater replenishment, the costs of spreading must also be included.

From the calculations in Table 1 and from Figure 3, we can be certain that prior to fiscal year 1954-55 increased deliveries of raw Colorado River water could have been made at a cost of not more than $5.72 per acre-foot. Additional softened and filtered water would have cost no more than $9.44 per acre-foot. Since local storm waters are available for spreading during only a small part

TABLE 1

Relationship Between Operating Expenses and Quantity Delivered
1946-47 and 1954-55[a]

	1946-47	1954-55	Difference
	dollars		
Operating costs (excluding costs of filtering and softening)			
Water storage in Lake Mead	18,786	100,847	82,061
Power and communication lines			
Transmission	27,687	37,251	9,564
Telephone	49,301	70,829	21,528
Pumping plants			
Operation	236,112	1,175,322	939,210
Power used	206,129	477,806	271,677
Water transportation			
Main aqueduct	38,183	57,473	19,290
Distribution system	103,750	239,637	135,887
General administration	340,210	659,973	319,763
Sundry			
Taxes, audit, etc.	79,375	58,658	- 20,717
Retirement	44,615	127,106	82,491
Total	1,144,148	3,004,902	1,860,754
Operating costs of softening and filtration plant			
Operation and maintenance	155,820	257,864	102,044
Cost of chemicals and power	383,128	568,324	185,196
Total	538,948	826,188	287,240
	acre-feet		
Total deliveries	60,386	385,946	325,560
Deliveries of softened water	60,074	137,284	77,210

(Continued on next page.)

TABLE 1--continued.

a/ Increase in importation costs per acre-foot of increase in delivery = $\frac{\$1,860,754}{325,560} = \$5.72$.

Increase in softening and filtration costs per acre-foot of increase in quantity = $\frac{\$287,240}{77,210} = \$3.72$.

Sources:

Metropolitan Water District of Southern California, Ninth Annual Report (Los Angeles, 1947), pp. 44 and 90.

Idem, Seventeenth Annual Report (Los Angeles, 1955), pp. 3 and 137.

of the year, facilities in the Montebello Forebay constructed to conserve local runoff can be used for spreading imported water during most of the year. Spreading imported water in these facilities costs approximately $1.50 per acre-foot.[1/] Additional water could have been imported and placed in underground storage for a cost of not more than $7.22 per acre-foot.

The Metropolitan Water District's contracts for firm energy from the Hoover and Parker power plants are for 1,750,000 kilowatt-hours during a 100 percent firm energy year; this is enough to pump approximately 850,000 acre-feet of water.[2/] Power for additional deliveries is bought from the Southern California Edison Company.

TABLE 2

Power Rates and Costs of Energy for Pumping

Source	Power rates	Energy costs
	mills per kilowatt-hour	dollars per acre-foot
Hoover power plant	1.761	3.68
Parker power plant	1.503	3.14
Southern California Edison Company	6.902	14.43

Source: Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), 175p.

There is no evidence of a major increase in marginal importation costs until 1959 when it became necessary to begin buying power from the Edison Company. Use of more expensive power increased marginal energy costs by approximately $11 per acre-foot and moved the marginal cost of delivering raw Colorado River water up to approximately $17 per acre-foot.

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1/ Interview with Clinton Milne, Civil Engineer, Los Angeles County Flood Control District, June 11, 1962.

2/ Metropolitan Water District of Southern California, Twenty-Third Annual Report, p. 15.

The costs per acre-foot of having brought in additional water indicates what the costs would have been to the communities making up the Metropolitan Water District, not the price at which it was selling water. The Metropolitan Water District Act specifies that rates for water should be set, insofar as possible, to cover all expenses.[1/] The Act also authorizes the levying of an ad valorem property tax to meet expenses not covered by water sales.

In 1938 an investigation revealed that the "out of pocket" costs of delivering Colorado River water would be low. To make Colorado River water competitive with the costs of producing local water, the price was originally set at $8.00 per acre-foot for untreated water (Table 3).

By 1948, the Metropolitan Water District Board of Directors realized that, irrespective of the low prices, Colorado River water was being purchased only when local supplies were insufficient.[2/] The price increase in 1948 was also prompted by the fact that the San Diego County Water Authority had annexed to the Metropolitan Water District and was purchasing substantial quantities.[3/] Price variations between 1948 and the late 1950's reflect variations in the Board of Directors' opinion as to the prices which would permit the lowest rate of assessment on property. By the late 1950's, the growing demand for Colorado River water permitted prices to be increased and the assessment rate to be decreased.

Due to increasing demands for current use, the Colorado River Aqueduct no longer has sufficient capacity to make up the accumulated overdraft. Water from northern California delivered to Los Angeles County under the State Water Plan will cost the Metropolitan Water District at least $60 per acre-foot.[4/]

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1/ Idem, Fifteenth Annual Report (Los Angeles, 1953), Appendix B, p. 161.

2/ Interview with Warren Butler, member of the Board of Directors, Metropolitan Water District of Southern California.

3/ Ibid.

4/ The price to the Metropolitan Water District will depend on the actual cost to the state. The canalside cost of water at Perris Reservoir, for the quantity expected to be delivered in 1990, has been estimated to be $58.90 in terms of 1960 prices. The Metropolitan Water District will bear the cost of conveyance from canalside to member areas; see Charles T. Main, Inc., Final Report, General Evaluation of the Proposed Program for Financing and Constructing the State Water Resources Development System of the State of California Department of Water Resources (Boston, 1960), Exhibit V-1.

TABLE 3

Price of Colorado River Water

Period		Normal use		Storage		For agricultural use and replenishment	
		Softened	Unsoftened	Softened	Unsoftened		
		dollars					
From	To						
December 20, 1940	June 30, 1948	15.00	8.00	a/			
July 1, 1948	June 30, 1950	18.00	8.00				
July 1, 1950	November 30, 1954	20.00	10.00				
December 1, 1954	April 30, 1955	18.00	8.00				
May 1, 1955	October 31, 1955	22.00	10.00				
November 1, 1955	November 30, 1955	18.00	8.00				
December 1, 1955	April 30, 1956			18.00	8.00		
December 1, 1955	June 30, 1957	20.00	10.00				
July 1, 1957	June 30, 1958	22.00	12.00				
July 1, 1958	June 30, 1960	25.00	15.00			22.00	12.00
July 1, 1960	January 1, 1961	23.00	15.00			20.00	12.00
January 1, 1961	January 1, 1962	25.00	17.00			20.75	12.75
January 1, 1962	January 1, 1963	27.00	19.00			21.50	13.50
January 1, 1963		29.00	21.00			22.25	14.25

a/ Blanks indicate no water was offered for sale in that price class.

Source: Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), 175p.

Viewed either in terms of the variable costs to the Metropolitan Water District or in terms of the prices at which it was selling water, filling the groundwater basins during the 1940's and early 1950's, and keeping them full would have been a good investment.[1/]

Summary

The construction of import facilities has proved to be only one step in stopping the overdraft on groundwater basins in Los Angeles County. The basins were overdrawn when additional water could have been imported at low variable cost.

Keeping the basins full would have been a good investment for the area as a whole. However, previous to any progress in integrating the management of imported and local groundwater supplies, there was no way for pumpers sharing a common basin to make a collective decision on the relative rates of pumping and purchasing. Neither the Metropolitan Water District nor the member agencies have had control over pumping. Furthermore, the member cities have been in competition with each other as well as with all other pumpers. An individual pumper purchasing imported water in lieu of pumping groundwater would only leave more groundwater for others pumping from the same basin.

PROGRESS DEPENDENT ON INSTITUTIONAL CHANGE

The experience of Los Angeles County provides specific evidence of the necessity of group action to coordinate interdependent interests in efficiently utilizing local and imported water supplies. However, the important question is how can the management of both types of supply be integrated? How can common objectives be evolved, and how can conflicting interests be resolved? To avoid repeating past mistakes, we need to know why some efforts failed while others succeeded.

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1/ As some vacant storage is needed for conservation of local water, the basins should not be completely filled with imported water.

The Metropolitan Water District of Southern California-- A Single-Purpose Agency

Although the Metropolitan Water District Act of 1927 is a general enabling act, it was written for the specific purpose of making possible the organization of a municipal corporation to deliver Colorado River water to the coastal plain of southern California.[1/]

Since the interested communities already had operating water distribution agencies, there was prompt agreement that the new district would sell at wholesale. A statement specifying that a metropolitan water district could sell only at wholesale was included in the enabling act.

Even before the aqueduct was completed, the Board of Directors foresaw the need for collective control over local groundwater basins; but the District did not have this control, and its enabling act specifically prohibited the condemnation of water or water rights already devoted to beneficial uses.[2/] Originally, the Metropolitan Water District Act limited membership to cities. None of the member cities, except Los Angeles, had any claim to exclusive rights to a groundwater basin, and Los Angeles had never been very successful in exercising its claims.[3/] To limit membership for administrative convenience, to insure that new members would be of sufficient size to make delivery economically feasible, and, where possible, to include entire groundwater basins or subbasins, the Board of Directors decided that annexations should be made in fairly large units rather than as individual cities. The State Legislature made this change in policy possible by amending the enabling act. There was hope that annexing large units would permit more effective management of local water production in conjunction with the use of Colorado River water, while eliminating the ruinous competition of irresponsible water users' taking a "free ride" by increasing

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1/ For history of the formation of the Metropolitan Water District of Southern California, see Vincent Ostrom, Water Supply (Los Angeles: The Hayes Foundation, 1953), 180p.; and Metropolitan Water District of Southern California, History and First Annual Report.

2/ Idem, Fifteenth Annual Report, Appendix B.

3/ Claims of the City of Los Angeles to first rights to the groundwaters of the San Fernando Valley will be discussed subsequently.

demand upon groundwater supplies instead of using the more expensive Colorado River water.[1/]

Beginning in 1942, all new members have been municipal water districts, except for the San Diego County Water Authority. With the formation and annexation of municipal water districts, most of the area overlying the major groundwater basins in the region served by the Metropolitan Water District has been brought into the District. Through either the cities or the municipal water districts, imported water has been made available to almost all large distributors and users. However, coverage of the basin by member agencies has not prevented groundwater basins from being overdrawn because the municipal water districts have no control over the right to pump from groundwater basins.

Even with its large areal extent, tremendous financial base, and powerful political influence, the Metropolitan Water District remains a single-purpose agency and can do little to coordinate the management of local and imported water.

Pumping Restrictions

California law governing the right to use percolating groundwater is limited almost entirely to that laid down by the courts in deciding specific cases.[2/]

Rights of overlying landowners are based on location and are essentially the same as riparian rights to surface water. Appropriative rights, which nonoverlying users can gain to water not needed by overlying users, have the same characteristics as appropriative rights to surface water. An appropriative right is for a specified quantity per year. If the supply is not sufficient to meet all appropriative rights, senior rights prevail over junior rights.

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1/ Ostrom, op. cit., p. 87.

2/ For a detailed discussion of California groundwater law, see Wells A. Hutchins, The California Law of Water Rights (Sacramento: California State Printing Office, 1956), pp. 418-514.

The Raymond Basin Adjudication--A New Doctrine Based on Prescription

The Raymond Basin adjudication was the first quantitative definition of substantially all of the rights to a groundwater basin in California and was the first usage of the court reference procedure in adjudicating groundwater rights.[1/]

The Raymond Basin, about 40 square miles in area, is separated from the rest of the San Gabriel Valley by the Raymond Fault, which is more or less impervious. The continuing overdraft on the groundwaters of the Basin prompted the City of Pasadena to call a meeting of the groundwater users.[2/] After a series of meetings brought no agreement on collective management of the Basin, the City of Pasadena, on September 23, 1937, initiated proceedings to adjudicate rights to the groundwaters of the Basin.[3/] Thirty-one pumpers were named as defendants.

Upon petition of 20 defendants, the court appointed the California Department of Public Works as Referee and asked that a detailed investigation be made of all physical facts, including a determination of the safe yield of the Basin and the history of use of each defendant. The Report of Referee was filed with the court on July 12, 1943.[4/]

Twenty-five parties to the suit formed an exchange agreement which allowed those without a surface water supply to meet demands in excess of their adjudicated share by purchasing pumping rights offered annually by those having a surface supply.

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1/ For a discussion of the court reference procedure as applied in both the Raymond Basin and West Coast Basin, see Snyder, "Economic Implications and Appraisal of the Court Reference Procedure for Allocating Ground Water," Water Resources and Economic Development of the West: Ground Water Economics and the Law, Report No. 5, Conference Proceedings of the Committee on the Economics Research Council (Berkeley, 1956), pp. 37-65.

2/ Duncan A. Blackburn, "The Adjudication of the Raymond Basin," Paper presented to the Southern California Water Coordinating Conference, Pasadena, California, November 21, 1961, p. 3.

3/ For history of litigation, see California Department of Water Resources, Watermaster Service in the Raymond Basin, for Period July 1, 1961-June 30, 1962 (Sacramento, 1962), pp. 2-6.

4/ California Department of Public Works, Referee, Report of Referee (The City of Pasadena v. The City of Alhambra, et al., no. Pasadena C-1323, May, 1954), p. 1.

In order to avoid the time and expense of a complete litigation, all parties except two stipulated to a proposed judgment.[1/] The Superior Court delivered a decision on December 23, 1944, and restricted pumpage by all parties except one which was included on July 1, 1945. In 1949 the State Supreme Court affirmed the decision with minor modifications. An appeal to the U. S. Supreme Court was denied in 1950.

Basis of Decision.--The Court held that there was an invasion of all rights when the overdraft occurred in 1913-14.[2/] No user was prevented from taking the quantity he needed. The injury consisted of the continual lowering of the water level and reducing the amount of water in underground storage, which would eventually render the supply insufficient to meet the needs of the rightful owners. Because the original owners continued to pump, the invasion was only partial. The prescriptive rights acquired against the original owners were limited to the extent that the original owners retained or acquired rights by their pumping:

> "The trial court fixed the right of each producer in terms of acre-feet per year at the highest continuous production of water for beneficial use in any five-year period before the filing of the complaint by each party, as to which there has been no cessation of use by the party during any subsequent continuous five-year period. Those who had not produced water for five consecutive years were decreed to have no right. All rights were then proportionally reduced so that total allowable extractions would equal the safe yield or average annual replenishment."[3/]

The Court appointed the Division of Water Resources as watermaster in charge of administering the judgment, which included the water rights exchange agreement.

While the adjudication restricted pumping in Raymond Basin, formation of the prescriptive rights doctrine encouraged pumping in other basins. The effects of the added incentive to pump and the limitations of a legislative attempt to remove it will be discussed.[4/]

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1/ California Department of Water Resources, op. cit., p. 14.

2/ For additional discussion of the decision, see Hutchins, op. cit., pp. 444-446.

3/ Kenneth K. Wright, "Underground Water Problems in California," Journal of American Water Works Association, Vol. 44, No. 8 (August, 1952), p. 663.

4/ For a more detailed discussion, see Snyder, "Economic Implications and Appraisal . . . ," pp. 51-53.

Subsequent Adjustments.--Since the average yield of a groundwater basin changes with changes in land and water use, there is no way of predicting the exact future yield. Recognizing that the future average yield would likely be different from the estimate, the Court retained the jurisdiction to make proportional adjustments in decreed rights.

Rising water levels from 1944 to 1950 induced the City of Pasadena to petition the Court for a redetermination of safe yield. The Court appointed the Division of Water Resources as Referee to redetermine the safe yield of the Raymond Basin. After an investigation by the Referee, the Court increased all rights by approximately 30 percent.1/

Although five years passed between the petitioning for a redetermination of safe yield and the changing of decreed rights, the fact that an adjustment was possible without a complete redetermination of rights is of considerable significance. Institutional flexibility permitting subsequent adjustments reduces the reliance on predictions of future safe yield.

While convenient adjustment is desirable, caution should be exercised that adjustments are not made so often that the Basin's storage capacity is not effectively utilized in smoothing out cyclical fluctuations in supply.

Once an adjudication is made, a prescriptive right is similar to an appropriative right in that the right is quantitatively defined. However, subsequent adjustments are made by adjusting the rights of all users as is normally characteristic of riparian rights.

The City of Sierra Madre operates a groundwater recharge project in the Raymond Basin. In October, 1950, the Court agreed to credit the City for water salvaged and directed the Watermaster to establish the amount salvaged.2/ The salvage credit can be either pumped or sold through the exchange pool.

West Basin--A More Complicated Adjudication

Overdraft in the 101,000-acre coastal basin began in the early 1900's.3/ By 1932, water levels were below sea level throughout most of the area, and

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1/ Infra, pp. 55-85.

2/ California Department of Water Resources, op. cit., pp. 18-23.

3/ West Basin and West Coast Basin are synonymous. For history of water development, litigation, and establishment of Watermaster Service, see idem, Report on Watermaster Service in West Coast Basin Watermaster Service Area, Los Angeles County, California, for Period June 1, 1960 through May 31, 1961 (Sacramento, 1961), pp. 3-9; also, Snyder, "Economic Implications and Appraisal. . . ."

seawater intrusion had become a serious problem along the entire coastal portion of the basin. Since 1932, the water levels have continued to decline.

Colorado River water has been available to the cities of Long Beach, Torrance, and Los Angeles since 1941. Imported water has been available to areas outside these cities since the West Basin Municipal Water District annexed to the Metropolitan Water District in 1948. As in other areas, making imported water available did not assure a reduction in groundwater extractions.

Legal proceedings to adjudicate groundwater rights in West Basin were initiated on October 24, 1945. The Court appointed the Department of Public Works as Referee and requested a completed investigation of all physical facts pertaining to groundwater supply and use in the Basin. The Report of Referee was filed with the Court on September 15, 1952.[1/]

No Possibility of Estimating the Basin's Annual Safe Yield.--With little exception, groundwaters throughout West Basin are in confined aquifers under positive hydrostatic pressure. The water level fell primarily as a result of decreases in pressure rather than a dewatering of the aquifers. This fall in hydrostatic pressure was due to both a decrease of the quantity in storage in the recharge areas (located in Central Basin) and the inability of the aquifers to transmit water as fast as it was being withdrawn without considerable loss in pressure.[2/]

The primary source of freshwater replenishment to the Basin is the underflow across the Newport-Inglewood uplift. A reduction in groundwater extractions would tend to curb seawater intrusion but would also reduce the flow of freshwater from Central Basin. As a compromise, the Referee recommended that extractions should initially be limited to 30,000 acre-feet per year, the average rate of replenishment during the period 1945-46 through 1949-50.[3/]

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1/ California Department of Public Works, West Coast Basin Reference--Report of Referee (California Water Service Company et al., v. City of Compton et al., no. 506806, June, 1952), 168p.

2/ For a comprehensive discussion of groundwater hydrology, see David Keith Todd, Ground Water Hydrology (New York: John Wiley & Sons, Inc., 1959), 336p.

3/ California Department of Public Works, West Coast Basin Reference . . . , p. 129. West Basin pumpers could have taken legal action to restrict upstream pumping. Their reasons for not taking such action will be discussed in a section on conflicts between basins; infra, pp. 55-85.

In November, 1956, the Court requested the State Water Rights Board, successor to the Department of Public Works as Referee, to make an investigation and bring physical facts up to date. The resulting investigation revealed that, during the period 1950-51 through 1955-56, the subsurface inflow across the Newport-Inglewood uplift had averaged only about 23,000 acre-feet per year.[1/] In the second part, the Referee recommended that extractions be initially limited to the prescriptive rights as of 1949.[2/] As the total prescriptive right is about 67,840 acre-feet per year, the recommended maximum was over twice that made in the first Report of Referee. Since freshwater replenishment was decreasing, it seems strange that this change was made with no explanation. It could have been due to a different weighting of the conflicting goals or a willingness to place greater dependence on the saltwater barrier being constructed to prevent seawater intrusion.

As water levels were below sea level throughout almost all of West Basin, the Referee estimated the rate of freshwater replenishment but refrained from stating that there was any safe yield. A more recent study stated that ". . . water levels on both sides of the uplift are equalizing and that underflow to the West Coast Basin has decreased and at some locations it is possible that the flow may be reversed."[3/]

Reduction in Overdraft Through an Interim Agreement.--In an effort to prevent the basin from being destroyed while litigation was in process, an interim agreement was negotiated. This agreement, which became effective on March 1, 1955, provided that those signing must restrict groundwater extractions to their prescriptive rights as of October 1, 1949.[4/] Prescriptive rights were defined as they had been in the Raymond Basin decision. The agreement was signed by 46 parties having over 70 percent of the total prescriptive right as of 1949.

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1/ California State Water Rights Board, West Coast Basin Reference Continuance, Report of Referee (Sacramento, 1961), p. 186.

2/ Ibid., p. 190.

3/ Los Angeles County Flood Control District, Report on Required Facilities for Replenishing and Protecting Ground Water Reserves in the Central and West Coast Ground Water Basins. Part I: Montebello Forebay Recharge Project, West Coast Basin Barrier Project (Los Angeles, 1961), p. 27.

4/ California Department of Water Resources, Report on Watermaster Service . . . , June 1, 1960-May 31, 1961, p. 5.

The agreement provided for the formation of an exchange pool, which would permit water users without surface water supplies to purchase pumping rights from those with connections.

Under the sponsorship of the West Basin Water Association, a committee of legal advisors representing the major groundwater producers prepared a proposed findings of fact, conclusions of law, and judgment for the purpose of hastening the completion of litigation. Parties representing 82 percent of the total computed "Prescriptive Right, 1949" signed the stipulation for judgment, which was filed with the Court.[1/] In a judgment entered on August 22, 1961, the Court defined the decreed rights of the 430 parties to the suit. Pumpers were restricted to their prescriptive right as of 1949.

The City of Hawthorne did not sign the stipulation for judgment and is appealing the judgment. The basis of the City's appeal will not be known until briefs are filed.

Conflict Between Coastal Plain and San Gabriel Valley

The main San Gabriel Valley encompasses some 105,000 acres and overlies a groundwater basin which is largely unconfined and extremely deep, having a known depth of over 1,600 feet in some areas. Surface and subsurface drainage passes through Whittier Narrows and supplies 80-90 percent of local water available to Central Basin.[2/] Hence, we see why the groundwater users of the coastal plain, particularly Central Basin, are so interested in the groundwater levels of the San Gabriel Valley.

Since 1944, groundwater levels in the main basin of the San Gabriel Valley have fallen by more than 75 feet.[3/]

According to a recent study, the falling water levels since 1944 have been due to the long period of less than average precipitation, rather than increases

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1/ Idem, Report on Watermaster Service in West Coast Basin Watermaster Service Area, Los Angeles County, California, for Period June 1, 1961 through September 30, 1961 (Sacramento, 1962), p. 8.

2/ Max Bookman, "Water Supply Problems in the Central Basin, Los Angeles County, California," Control and Reduction of Ground Water Pumping in the Central Basin (Downey, California: Central Basin Water Association, 1961), pp. 1-5.

3/ Koebig and Koebig, Inc., The Need for Supplemental Water, A Report for the Upper San Gabriel Valley Municipal Water District (Los Angeles, 1961), p. S-3.

in water use.[1/] There was an increase in the amount of sewage exported to ocean outfalls and a consequent decrease in water returning to the groundwater basin from cesspools and septic tanks. However, this was offset by a decrease in consumptive use due to a shift in land use from irrigated agriculture to urban.

Regardless of the reason for the falling groundwater levels in the San Gabriel Valley, this decline has reduced the flow to Central Basin. In addition, water use above Whittier Narrows is expected to increase because much of the future urban expansion will be on land not presently under irrigation.

On May 12, 1959, the City of Long Beach, City of Compton, and Central Basin Municipal Water District filed a complaint with the Superior Court of Los Angeles County against all appropriators of water in the San Gabriel Valley.[2/] The plaintiffs requested that the defendants state the nature and extent of their claims and that each defendant be restricted to his right as determined by the Court.

The parties to the case are attempting to reach an agreement in the form of a stipulated judgment which shall provide for continuing jurisdiction of the Court and the right of the Court to modify the judgment. Negotiating committees for the plaintiffs and defendants have agreed on general principles of settlement.[3/] This agreement was preliminary and not binding on any party of the suit.

Although the plaintiffs originally wished to have the rights of individual defendants determined, the negotiating committees are hoping to make a final agreement in terms of the flow to the lower area, leaving the defendants to formulate and agree upon the manner of allocating the obligations to be assumed by the upper area.[4/]

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1/ Stetson, Strauss and Dresselhaus, Inc., A Supplemental Water Supply for Upper San Gabriel Valley Water District (Los Angeles, 1962), pp. I-4 through I-6.

2/ The commonly used short name for this case is "Long Beach v. San Gabriel."

3/ Stetson, Strauss and Dresselhaus, Inc., op. cit., Appendix B, 1961, pp. B-1 through B-5.

4/ A supplemental supply will be needed in the upper area. Alternative sources are discussed; see infra, pp. 55-85.

Current Proceedings to Adjudicate Rights in Central Basin

As a result of decreasing flow from the San Gabriel Valley and increased pumping, groundwater overdraft began to be a serious problem throughout Central Basin in the 1940's. In 1944-45 overdraft was 22,000 acre-feet, and by 1949-50 it had increased to 77,000 acre-feet per year.[1/]

Sixty agencies, comprising 70 percent of the total groundwater production in the Basin, formed the Central Basin Water Assocation in September, 1950.[2/] Through this Association the Central Basin Municipal Water District was formed. The District annexed to the Metropolitan Water District of Southern California in November, 1954, making Colorado River water available to those areas outside the cities of Los Angeles, Compton, and Long Beach, which have had access to Colorado River water since 1941.

Again, the availability of imported water has not assured a reduction in groundwater extractions. There is approximately 1,000,000 acre-feet of vacant storage in Central Basin.[3/] Water levels are more than 100 feet below sea level in some parts of the Basin, and seawater intrusion is a serious problem in the Alamitos Gap area.

As will be discussed in more detail in the following section, large quantities of imported water are being purchased for replenishment by Zone I of the Los Angeles County Flood Control District and the Central and West Basin Water Replenishment District. However, replenishment alone cannot stop the falling water levels in a great portion of the Basin except by injection through wells because the aquifers are confined under 70 percent of Central Basin and they cannot transmit water as fast as it is being withdrawn.[4/] Water levels in the confined area can be raised economically only if pumping is reduced.

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1/ Central Basin Water Association, "Synopsis of Historical Events Affecting the Solution of Water Problems in the Central Basin, Los Angeles County," Control and Reduction of Ground Water Pumping in the Central Basin (Downey, California, 1961), p. 1.

2/ Ibid.

3/ Statement by Carl Fossette in California Legislature, Assembly Interim Committee on Water, op. cit., p. 128.

4/ Bookman, Edmonston, and Gianelli, "Proposed Adjudication of Ground Water Rights in Central Basin," Control and Reduction of Ground Water Pumping in the Central Basin (Downey, California: Central Basin Water Association, 1961), p. 6.

Increased pumping costs due to lower water levels and, beginning in 1960, an assessment on groundwater extractions levied by the Central and West Basin Water Replenishment District reduced the difference between the costs of producing groundwater and purchasing Colorado River water. However, reduction of the cost differential did not result in decreased pumping, even where water levels were falling rapidly.[1/]

After careful study of the means of accomplishing a reduction in pumping, the Central Basin Water Association concluded that it would be necessary to file legal action for adjudication of groundwater rights in Central Basin.[2/] Since pumping in West Basin is presently restricted to about 75 percent of what was being pumped when their suit was filed in 1949, Central Basin pumpers are considering a 25-percent reduction from total 1960-61 pumping.[3/]

After deciding to adjudicate rights, the pumpers in Central Basin immediately began negotiations to reduce pumping through an interim agreement and form a water rights exchange pool. These negotiations were begun even before legal action was filed by the Central and West Basin Water Replenishment District on January 2, 1962. An interim agreement was formed in record time and became effective October 1, 1962. This agreement involved 46 producers representing 77.6 percent of the total assumed relative rights.[4/]

The provisions of the interim agreement and the current negotiations for a final settlement will be discussed in a later section.[5/]

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1/ An analysis will be made of why individuals were so reluctant to reduce pumping even when imported water could be purchased at approximately the same cost and a law (Sections 1005.1 and 1005.2 of the California Water Code) had been passed to protect the groundwater rights of those willing to purchase imported water to reduce extractions from an overdrawn basin. Infra, pp. 55-85.

2/ Bookman, Edmonston, and Gianelli, op. cit., p. 2.

3/ It seems rather likely that West Basin pumpers will request the Court to restrict pumping in Central Basin to something comparable to a 25-percent reduction from total extractions in 1949 rather than 1960-61.

4/ Telegram from Carl Fossette to Carley V. Porter (reprinted in Ground Water Problems in California, Report of the Assembly Interim Committee on Water, Vol. 26, No. 4, 1961-1963, p. A-39).

5/ Infra, pp. 55-85.

Conflict Over Rights in the San Fernando Valley

Although the Court held in 1909 that the pueblo right of the City of Los Angeles extended to the full underground supply of the San Fernando Valley, the City of Los Angeles has not been able to gain control of the Basin.[1/] A Court decision in 1943 stated that Los Angeles could store Owens River water in the underground basin of the San Fernando Valley without losing its rights to the imported water.[2/] The same decision reaffirmed the rights of Los Angeles to all natural groundwaters of the San Fernando Valley needed for use within the city. In 1953 the City of Los Angeles initiated injunctive action against the other pumpers in the Valley. This case is still in the courts.

Los Angeles estimates the safe yield of the Basin to be 91,500 acre-feet per year and has been pumping at approximately this rate since 1950.[3/] The cities of Glendale, Burbank, and San Fernando have not been restricted; during the fiscal year 1960-61 they pumped a total of 45,000 acre-feet. In addition, some 200 small pumpers are taking an unknown quantity which is estimated to be no more than a few thousand acre-feet per year. The quantity in storage decreased by over 500,000 acre-feet between 1944 and 1958.[4/]

The cities of Los Angeles, Glendale, and Burbank are members of the Metropolitan Water District and could have been purchasing more imported water as none of them has ever taken more than one-fourth of its entitlement. Los Angeles claims rights to all the groundwater and pumps what it estimates to be the average safe yield. Both Glendale and Burbank have drawn their base supply from the underground and purchased Colorado River water to meet peaks in demand.

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1/ Under its pueblo right, the City of Los Angeles claims first right to the entire flow of the Los Angeles River if needed for use within the city. In 1909 the Court recognized the groundwater basin of the San Fernando Valley as the source of the Los Angeles River and held that the City's pueblo right extended to the full underground supply. For a legal discussion of the pueblo right, see Hutchins, op. cit., pp. 256-262.

For a detailed discussion of the early conflicts on water rights in the San Fernando Valley, see Ostrom, op. cit., p. 71.

2/ Hutchins, op. cit., p. 72.

3/ Statement by M. Socha for Los Angeles City Department of Water and Power in California Legislature, Assembly Interim Committee on Water, op. cit., pp. 113-114.

4/ Ibid., p. 144.

In fiscal year 1960-61, Burbank pumped 20,401 acre-feet and purchased 4,919 acre-feet; Glendale pumped 21,240 acre-feet and purchased 2,772 acre-feet.[1/]

As an alternative, the overdraft could have been prevented by replenishing the Basin with imported water. Between 1931 and 1943, the City of Los Angeles spread a total of approximately 170,000 acre-feet of surplus Owens River water.[2/] Since that time, Los Angeles has cooperated with the Los Angeles County Flood Control District in conserving local runoff but has not used imported water for replenishment. Owens River water is preferred to Colorado River water for spreading because the Owens River water is of higher quality and, due to the design of the system, can be delivered to the spreading areas more conveniently.[3/] The author would not propose that there has been a surplus of water in the Owens Valley; however, by buying more Colorado River water for direct delivery, Los Angeles could have used Owens River water for replenishment.

The physical facilities to prevent the overdraft have been available, but the necessary organizational structure has not. Why should one city purchase more Colorado River water in order to reduce pumping for the benefit of the others? Likewise, why should Los Angeles purchase more Colorado River water and use Owens River water for replenishment when the benefits must be shared with the other pumpers?

Upon a petition of the defendants, the Court referred the case of Los Angeles vs. all other pumpers from the San Fernando Valley to the State Water Rights Board for an investigation of all facts pertaining to it. The Board has made a complete investigation of the safe yield of the Basin and of the history of use of each pumper.[4/] This detailed investigation would be necessary for the adjudication of rights on the basis of prescription but does not appear relevant in deciding whether or not prescriptive rights have been gained

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1/ Metropolitan Water District of Southern California, Twenty-Third Annual Report, p. 50.

2/ California Legislature, Assembly Interim Committee on Water, op. cit., p. 117.

3/ Ibid., p. 112.

4/ California State Water Rights Board, Referee, San Fernando Valley Reference, Report of Referee, Vol. 1 (The City of Los Angeles v. The City of San Fernando et al., no. 650079, July, 1962), 258p.

against the pueblo right claimed by Los Angeles. Since delaying the decision is to the advantage of the defendants, the request for a full investigation of the history of use of each pumper may have been primarily a delaying action.

With Los Angeles claiming a paramount right, the case will eventually be taken to the highest court that will hear it. Meanwhile, there appears to be no basis for negotiating an interim agreement either to reduce pumping or to collectively purchase water for replenishment.

Summary on Adjudication

Although time consuming and expensive, the adjudication of Raymond Basin has greatly facilitated management of the groundwater resource. Experience in West Basin has been less encouraging. Since West Basin is replenished almost entirely by underground flow from Central Basin, little could be accomplished by restricting extractions from West Basin while pumpage from Central Basin was being increased. Recognizing the importance of interbasin flows, the Central Basin pumpers initiated action to limit extractions from the upstream San Gabriel Valley before they began the adjudication of rights within Central Basin.

Thus far, agreement by most parties on a substantial number of issues appears to have been essential for successful adjudication. While agreement should certainly be encouraged, there must be a way of litigating those cases where an agreement cannot be reached. Possible improvements in adjudication procedure will be analyzed.[1/]

Importation for Groundwater Replenishment

After 1943, when the City of Los Angeles stopped replenishing the basin under San Fernando Valley with Owens River water, no water was imported into Los Angeles County for replenishment until 1954. We shall see that available import and spreading facilities were of no use until acceptable institutional arrangements for purchasing water were found.

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1/ *Infra*, pp. 55-85.

No Lack of Physical Facilities for Spreading

The aquifers of the coastal plain are sufficiently connected and exposed to the surface to permit significant recharge by spreading only in the Montebello and Los Angeles Forebay areas. As the Los Angeles Forebay is almost completely covered by urban development, only the Montebello Forebay, located just below Whittier Narrows, is available for spreading.

The objectives of the Los Angeles County Flood Control District have always included both flood control and water conservation. Natural percolation of precipitation in the Forebay areas of the coastal plain had been reduced by urbanization. Lining the channels of the Rio Hondo and the Los Angeles Rivers for flood protection also prevented percolation of streamflow. To compensate for these losses and provide for maximum conservation of local water, the Los Angeles County Flood Control District constructed spreading facilities adjacent to both the San Gabriel and Rio Hondo Rivers. Spreading operations began in 1938.

As local water is available for spreading during only a small part of the year, these facilities are available for spreading imported water during most of the year. The expenses of conserving local water are paid from the District's general funds, derived from an ad valorem tax on real property; however, these funds cannot be used for purchasing imported water for replenishment.

Legislative Authorization Creates Possibilities for Group Action

Interested parties in Los Angeles County have been able to obtain legislative action which has made group action possible through the organizational framework of the local public district.

New Powers for the Los Angeles County Flood Control District.--In 1951 the California Legislature amended the Los Angeles County Flood Control District Act to provide for the establishment of zones within the District for the purpose of purchasing imported or reclaimed water for replenishing groundwater basins.[1/] The District Board of Directors has authority to initiate proceedings which can be stopped by written protests of either the owners of property having at least 10 percent of the total assessed value in the proposed

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1/ California, Statutes and Amendments to the Codes, Vol. 1 (1951), c. 971, pp. 2592-2597.

zone or the governing bodies of cities and water-supplying districts having at least 60 percent of the total assessed value.

Within a zone a special tax not in excess of 5 cents per $100 of assessed value of real property may be levied for acquiring and conserving water. Unless renewed, zones terminate at the end of five years. Renewal may be stopped by a majority vote of the governing bodies of cities and water-supply districts having at least 35 percent of the total assessed value.

A New Enabling Act.--In 1953 a bill was introduced in the California Assembly to amend the Metropolitan Water District Act and make possible the formation and operation of special water replenishment districts.[1/] The authority to form replenishment districts and the control over them was to be vested in the board of directors of the parent metropolitan water district. The bill authorized the levying of a replenishment assessment on the production of groundwater within a replenishment district; the proceeds were to be used for the acquisition, delivery, and injection or spreading of water for replenishment purposes. As the bill did not limit the rate at which groundwater production might be assessed, passage of the bill would have given the board of directors almost complete control over the use of groundwater basins. Without becoming a major political issue, the bill was referred to an interim committee for study.

The Water Replenishment District Act, passed in 1955, authorizes the formation of districts with the power to assess groundwater extractions to finance replenishment activities.[2/] Districts formed under this Act are independent of any metropolitan water district.

Upon petition of at least 10 percent of the voters in a proposed replenishment district, the California Department of Water Resources will conduct an investigation and hold hearings concerning the formation of the district and delineation of boundaries. If the Department of Water Resources recommends formation of a district, an election is called. All registered voters may vote.

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1/ California, Legislature, Assembly Bill No. 2699, Reg. Sess. (1953), Amended, 1953.

2/ California, Water Code, Div. 18. The Act applies only to the area within the exterior boundaries of the counties of Santa Barbara, Ventura, Los Angeles, San Diego, Riverside, San Bernardino, and Orange, except those areas within Orange County Water District.

Once formed, a district is governed by a board of directors, with one being elected from each of five divisions.

A district's purpose is the replenishment of groundwater supplies. To accomplish this end, a variety of powers are provided, including authority to buy and sell water, to distribute water to persons in exchange for ceasing or reducing groundwater extractions, to spread and inject water for replenishment, and to initiate proceedings to adjudicate groundwater rights.

The enabling act authorizes the assessment of groundwater production within the district for replenishment purposes.[1/] Each year, after gathering facts through an engineering survey and public hearings, the board of directors sets the assessment rate.

Within the limits (which may not exceed 20 cents per $100 assessed value) set in the petition to form a district, the board of directors may levy a tax on the assessed value of real property.

Progress Through Public Districts

Zone I of the Los Angeles County Flood Control District.--Under the amendment passed in 1951, Zone I--encompassing most of Central Basin as shown on Figure 4--was established in 1952. The maximum assessment of 5 cents per $100 was levied. In 1954, Zone I began purchasing untreated Colorado River water, which was percolated in unlined river channels and the Rio Hondo and San Gabriel spreading grounds.[2/] The costs of spreading have been paid from the general funds of the Los Angeles County Flood District. Purchases have been made through members of the Metropolitan Water District located in Central Basin (for annual purchases, see Table 4).

The zone was reconstituted in 1957 and again on July 1, 1962, with the provision that funds may be used for construction as well as for purchasing

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1/ The Act provides that, in the event of an adjudication of all or substantially all of the rights to a basin, one's adjudicated share of natural safe yield shall be exempt from the assessment; ibid., Div. 18, secs. 60350-60352, c. 6. The possible effects of this provision will be discussed; infra, pp. 55-85.

2/ Los Angeles County Flood Control District, op. cit., p. 19.

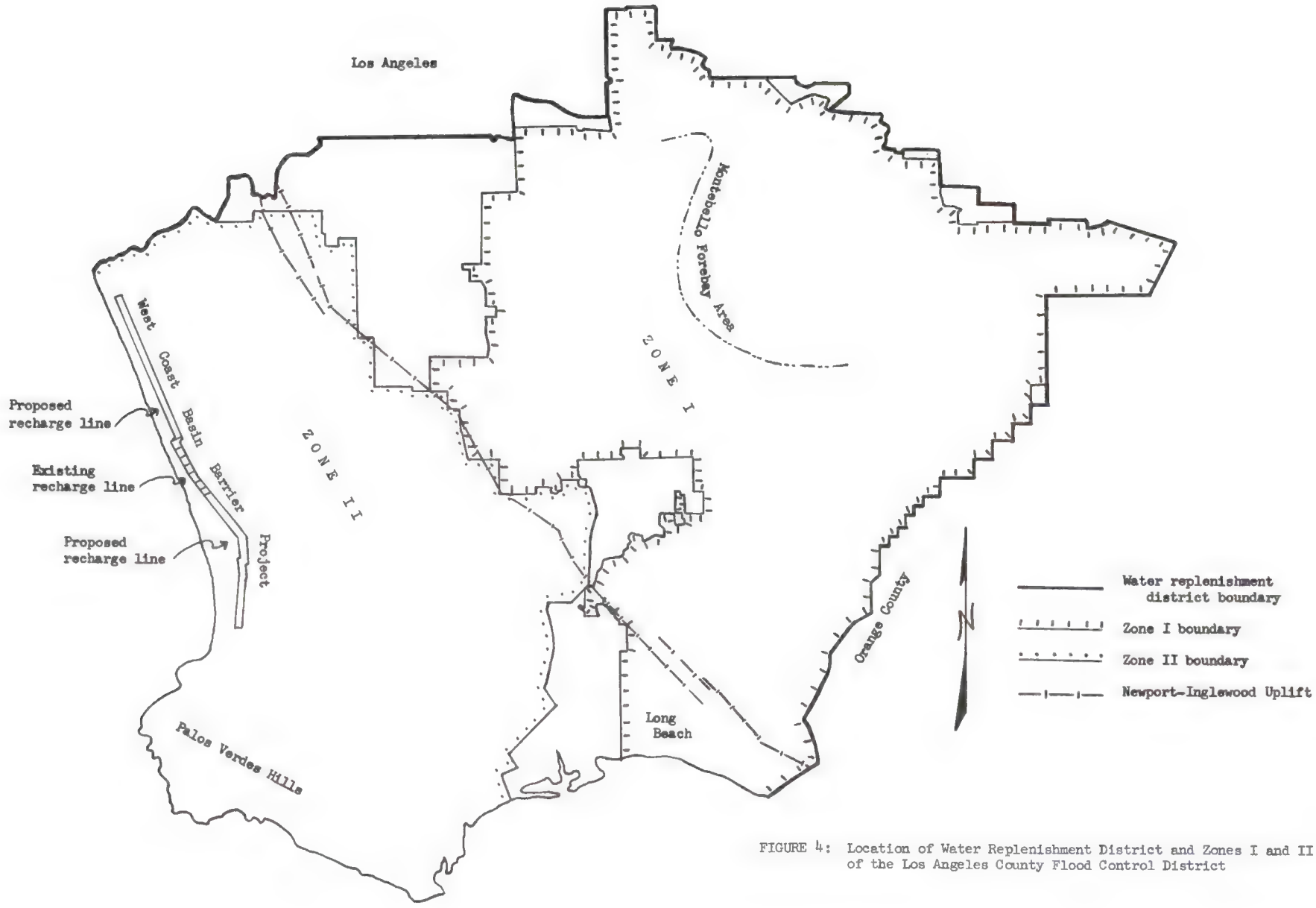

FIGURE 4: Location of Water Replenishment District and Zones I and II of the Los Angeles County Flood Control District

TABLE 4

Imported Colorado River Water Delivered for Spreading and Injection in the Central and West Basin Water Replenishment District

Water year	Untreated water delivered for spreading in Montebello Forebay		Treated water delivered for injection at West Coast Basin Barrier Project	
	Los Angeles County Flood Control District, Zone I	Central and West Basin Water Replenishment District	Los Angeles County Flood Control District, Zone II	Central and West Basin Water Replenishment District
	acre-feet			
1952-53	0	0	1,060	0
1953-54	30,000	0	3,300	0
1954-55	24,800	0	2,780	0
1955-56	56,000	0	2,810	0
1956-57	50,000	0	3,530	0
1957-58	105,100	0	4,270	0
1958-59	54,400	0	3,640	0
1959-60	80,900	0	3,700	0
1960-61	80,800	67,000[a/]	1,510	2,910[c/]
1961-62	[b/]	151,000[c/]	0	5,700[c/]
Total	482,000	218,000	26,600	8,610

a/ Includes 650 acre-feet of treated water delivered at the spreading grounds during May, June, July, and August for insect control research.

b/ All available Los Angeles County Flood Control District funds are assumed to be utilized for construction of Alamitos Barrier Project until July, 1963, unless the Replenishment District is unable to purchase all the water available for replenishment.

c/ Estimated.

Source: Bookman, Edmonston, and Gianelli, Annual Survey Report on Ground Water Replenishment (Downey, California: Central and West Basin Water Replenishment District, 1962), p. 21.

water.[1] The alteration will permit the use of Zone I funds for construction of the Alamitos Barrier Project which will be discussed shortly.

Central and West Basin Water Replenishment District.--A petition proposing formation of the Central and West Basin Water Replenishment District was filed on June 9, 1959. Proceedings moved very rapidly. A hearing on the proposed District was held on July 6, 1959, and the Department of Water Resources published its report before the end of the month.[2]

On November 17, 1959, the voters approved the proposed District by a 4 to 1 majority.[3] The District, shown on Figure 4, includes both Central and West Basin, and some hill areas which receive water from these Basins.

The petition to form the District limited the power to tax property to that sufficient to pay the operating expenses of the District.[4] Since the costs of spreading and injecting are paid by the Los Angeles County Flood Control District, the operating expenses of the Replenishment District have been small and have been covered by a tax which has never exceeded .005 cent per $100 of assessed value.

The Replenishment District has been purchasing untreated Colorado River water for spreading in the Montebello Forebay and treated water for injection at the West Basin seawater barrier project (see Table 4 for annual purchases). These purchases have been made with funds from an assessment on all groundwater production within the District. The assessment rate has moved up from $3.19 per acre-foot in 1960-61 to $5.75 in 1961-62 and to $6.63 in 1962-63.[5]

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1/ Bookman, Edmonston, and Gianelli, Annual Survey Report on Ground Water Replenishment (Downey, California: Central and West Basin Water Replenishment District, 1962), p. 53.

2/ California Department of Water Resources, Report of Proposed Central and West Basin Water Replenishment District (Los Angeles, 1959), p. 2.

3/ Statement by Carl Fossette in California Legislature, Assembly Interim Committee on Water, op. cit., p. 128.

4/ California Department of Water Resources, "Petition for Formation of a Water Replenishment District," Report on Proposed Central and West Basin Replenishment District, p. B-3.

5/ Bookman, Edmonston, and Gianelli, Annual Survey Report . . . , pp. 11-12 and 69.

Reclamation of Waste Water for Replenishment.--A reclamation plant will soon begin operations at Whittier Narrows. Waste water from the San Gabriel Valley will be reclaimed and spread at the Montebello Forebay recharge area. The plant will be small, having a capacity of only 10,000 acre-feet per year; however, the project is a milestone of interagency cooperation.

Under a four-party agreement, the County contributed the funds for designing and constructing the plant.[1/] The Sanitation District agreed to design, build, maintain, and operate it. The Replenishment District will buy the water at a price equal to the lowest rate currently charged by the Metropolitan Water District for untreated water for replenishment purposes. The Sanitation District will reimburse the County. The Flood Control District agreed to spread the water at its own expense. Similar interagency arrangements have been made to finance and manage saltwater barrier projects.

Saltwater Barrier Projects

The confined aquifers of the coastal portions of Los Angeles County are below sea level; however, under natural conditions pressure in the aquifers was sufficient to maintain a hydraulic gradient toward the ocean. Groundwater extractions have been sufficient to lower pressure enough to reverse the natural gradient and result in seawater intrusion. The importance of protecting the aquifers from seawater will become increasingly evident as the study progresses.

West Basin Barrier Project.--For research purposes, 12 injection wells were installed to protect about 8,200 feet of the West Basin coastline.[2/] This pilot project proved successful. In 1954, Zone II of the Los Angeles County Flood Control District was established to purchase water for the continued operation of the facilities. The Zone was renewed in 1959. The Central and West Basin Water Replenishment District is currently purchasing water for injection, thereby freeing Zone II funds to be used for construction of new facilities.

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1/ Unpublished contract, "Reclamation Water Contract," among County of Los Angeles, County Sanitation District No. 2 of Los Angeles County, Los Angeles County Flood Control District, and Central and West Basin Water Replenishment District, signed February 1, 1961.

2/ For history of development of barrier project, see Los Angeles County Flood Control District, op. cit., pp. 60-62.

Facilities are being expanded as shown on Figure 4. A total of 64 injection wells will be needed. Construction costs are being paid from general funds of the Flood Control District and from funds collected by Zone II. Water will be purchased by the Replenishment District; other operating expenses will be paid by the Flood Control District.

Proposed Alamitos Barrier Project.--The Alamitos Gap area, located at the mouth of the San Gabriel River, has a serious seawater intrusion problem. The most practical method of control appears to be a freshwater pressure barrier located so as to encircle the majority of the intruded area.[1/]

Since the intruded area is in both Los Angeles and Orange Counties, negotiations are being made for construction and operation on a cooperative basis, with the Orange County Water District responsible for the Orange County share of the project. The Los Angeles County share will be a cooperative endeavor; the Los Angeles County Flood Control District will be responsible for construction and operation, using both its general funds and Zone I funds for construction; and water will be purchased by the Central and West Basin Water Replenishment District.[2/]

Recapitulation

The Metropolitan Water District has been able to play only a limited role in promoting effective joint utilization of imported and local groundwater supplies. Without authority to restrict groundwater extractions, the District could encourage a shift to the use of more Colorado River water only through persuasion and pricing policy. The District has no authority to levy taxes to finance groundwater replenishment activities. However, water in excess of that needed for supplying demand for current use has been made available for replenishment purposes at especially low prices.

Proceedings to adjudicate groundwater rights have been initiated for several basins. Only the Raymond Basin adjudication has been completed to the point that all possibilities for appeal have been exhausted. The rate of

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1/ Idem, Report on Required Facilities. . . . Part II: Alamitos Barrier Project (Los Angeles, 1962), 44p.

2/ Ibid., pp. 4-5.

progress in current adjudication proceedings varies from the deadlocked struggle in the San Fernando Valley to the rapidly progressing case in Central Basin.

The use of Colorado River water for replenishing overdrawn groundwater basins was delayed several years due to the absence of an appropriate organizational structure. Group action to purchase imported water for replenishment was possible after legislation expanded the powers of the Los Angeles Flood Control District and authorized the formation of water replenishment districts.

Fully integrated management of ground and surface water has not been achieved. After discussing the potential role of groundwater basins in supplying future water needs, the study will focus on the integration of management necessary for the realization of this potential.

THE POTENTIAL ROLE OF GROUNDWATER BASINS IN SUPPLYING FUTURE WATER NEEDS

From the historical evidence, it can be concluded that the advantages of jointly utilizing surface facilities and groundwater basins have been known for several decades and that failures to achieve joint utilization have been due to the absence of appropriate incentives and the absence of an adequate organizational structure. However, the institutional problems must be studied as they relate to physical and engineering considerations.

After developing the concept of conjunctive use and briefly reviewing research on the application of the concept, basic plans for supplying future water needs will be formulated. This information and the lessons from past experience will serve as a basis for evaluating the present institutional structure and exploring possibilities for improvements.

Concept of Conjunctive Use

Water is needed at particular points in time and space.[1/] Since water is simultaneously distributed through both dimensions, storage and conveyance are

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1/ The influence of cost and institutional factors on the quantity used will be discussed; infra, pp. 55-85.

highly interdependent functions. At various stages in a given system, storage space can, within limits, be substituted for conveyance capacity. The advantages of conjunctively utilizing surface facilities and groundwater basins stem from this relationship between storage and conveyance.

The potential role of groundwater basins in supplying seasonal peaks in demand and in smoothing out seasonal and cyclical fluctuations in local supply has been generally recognized for some time. Less attention has been given to the possibility of reducing long-run costs by building up groundwater reserves following an expansion in import facilities and drawing from these reserves during the years preceding the next expansion in import capacity.

In addition to their storage and conveyance roles, groundwater basins can be utilized for improving water quality. Turbidity, organic content, and bacterial contamination can be removed from either surface water or reclaimed sewage by percolation through natural aquifers.1/

The concept of conjunctive use is simply that of jointly utilizing surface facilities and groundwater basins to supply the desired yield of water at minimum cost.2/ In The California Water Plan, this concept is referred to as "conjunctive operation."3/

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1/ For additional discussion of the potential functions of groundwater basins, see:

James H. Krieger and Harvey O. Banks, "Ground Water Basin Management," California Law Review, Vol. 50, No. 1 (March, 1962), pp. 57-58.

Todd, op. cit.

2/ This is the commonly used definition of conjunctive use. It must be noted, however, that on at least one occasion the concept of conjunctive use has been defined to include the optimum level of water use and the optimum allocation among uses as well as the minimum cost method of jointly supplying the water from both surface and underground sources. See Oscar R. Burt, "The Economics of Conjunctive Use of Ground and Surface Water" (unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, Berkeley, 1962), 219p.

3/ California Department of Water Resources, The California Water Plan, Division of Resources Planning Bulletin No. 3 (Sacramento, 1957), pp. 206-211.

Research on the Application of Conjunctive Use

Efficient utilization of ground and surface water resources depends on the solution of difficult problems in the area of engineering economics as well as on the integration of management. Since the factors influencing supply and demand are constantly changing, the rate and location of groundwater extractions, of direct delivery of surface water, and of groundwater replenishment must be adjusted daily. Even more difficult problems are encountered in choosing the size; location; and date of construction of aqueducts, surface reservoirs, distribution facilities, wells, pumps, and replenishment facilities.

Optimization Models

Formal programming, which grew out of research on planning for the U. S. Air Force during World War II, is now attracting widespread attention in many of the natural and social sciences.[1/] As a basis of broad national policy decisions in the area of water resource development and use, the relevance of quantitative optimizing is seriously limited by (1) the difficulties in evaluating extramarket benefits and costs, (2) the influence of monopoly and government on market prices, (3) the inclusion of social institutions as constraints, and (4) the difficulties in allowing for uncertainties.[2/] Formal programming is more applicable to a specific problem such as the determination of the minimum cost method of supplying water at a particular rate to an area of limited size. Market prices are valid measures of cost to a local agency, and the limited size of the problem makes feasible the determination of the minimum cost plan under alternative sets of institutional constraints. Methods of allowing for uncertainties will be discussed subsequently.

Linear programming, the first formal program to be developed, is an operationally efficient technique for finding the maximum or minimum of a linear

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1/ For discussion of the origin and subsequent applications of formal programming, see Ciriacy-Wantrup, "Conservation and Resource Programming," Land Economics, Vol. 37, No. 2 (May, 1961), pp. 105-111. (University of California, Giannini Foundation Paper 207.)

2/ For additional discussion of these limitations, see ibid.

function of variables subject to linear inequalities.[1/] If each of the various processes for supplying water can be written as linear functions of the factors needed to deliver water with each process and if the cost per unit of water delivered in each process is linear, the optimum quantity to be delivered with each process can be readily computed. The basic technique can be altered to permit the inclusion of linear transformations of nonlinear functions.

Unfortunately, the basic linear programming model applies only to a static situation. A modification known as dynamic linear programming permits inputs and outputs to be dated and to have different magnitudes in different time periods, but there are no provisions for uncertainty or for incorporating changes in prices or input-output coefficients.[2/] The important questions in jointly utilizing ground and surface water resources stem from fluctuations in supply, growth in demand, and institutional and technological changes. To be of much assistance, an optimization technique must deal with these problems of change through time.

More recent developments in formal programming give promise of overcoming some of the limitations of linear programming and dynamic linear programming. A method known as dynamic programming has been developed which provides a systematic approach to problems involving a multistage decision process.[3/] With dynamic programming, complex problems can be studied by parts or stages. In situations involving a sequence of decisions through time, new information can be introduced as it becomes available. Risk can be incorporated if the probabilities of future events can be estimated as in the case of future precipitation.

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1/ For a concise statement of the technique, see George B. Dantzig, "Maximization of a Linear Function of Variables Subject to Linear Inequalities," Activity Analysis of Production and Allocation, ed. T. C. Koopmans (New York: John Wiley & Sons, Inc., 1951), pp. 339-347.

2/ Laurel D. Loftsgard and Earl O. Heady, "Application of Dynamic Programming Models for Optimum Farm and Home Plans," Journal of Farm Economics, Vol. XLI, No. 1 (February, 1959), pp. 51-62. The method used is really dynamic linear programming and is referred to as such in the text of the article.

3/ For a presentation of the dynamic programming method, see Richard Bellman, Dynamic Programming (Princeton: Princeton University Press, 1957), 342p.

For additional applications, see Richard E. Bellman and Stuart E. Dreyfus, Applied Dynamic Programming (Princeton: Princeton University Press, 1962), 363p.

A theoretical dynamic programming model dealing with the joint utilization of ground and surface water was published in 1961.[1/] In each of two recently completed dissertations, dynamic programming was used in determining the optimal management of ground and surface water.[2/] Both studies dealt with actual situations, but many simplifying assumptions were made. Burt used linear programming to estimate the optimum allocation of water among various water-using activities and dynamic programming to estimate the marginal value of water imported at various points in time. Buras concentrated on the problems of supplying water at minimum cost and used dynamic programming for the entire analysis. The Buras model accounts for transmissibility limitations and is, therefore, more applicable in the case of confined aquifers.

Investigations by the Department of Water Resources

During the 1959 session, the legislature appropriated funds to finance an intensive investigation of the groundwater basins of southern California. The objective of the program ". . . is to formulate a coordinated plan of operation that will permit the maximum utilization of these groundwater basins in conserving the local water supply and in storing and distributing imported water."[3/] For each basin investigation, the work program is divided into three phases: geology, hydrology, and operation and management. The first two phases will be published as interim reports and will provide information for the third phase in which alternative plans for coordinated operation of the groundwater basin will be developed and compared.

The groundwater basins underlying the coastal plain of Los Angeles County have been selected for the first investigation. The geological and hydrological phases have been completed.[4/] Since the operations and management phase

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1/ Nathan Buras and Warren A. Hall, "An Analysis of Reservoir Capacity Requirements for Conjunctive Use of Surface and Groundwater Storage," International Association for Scientific Hydrology, Ground Water in Arid Zones, Publication No. 57 (Gentbrugge, Belgium, 1961), pp. 556-563.

2/ Nathan Buras, "On the Optimal Operation of a Dam and Aquifer Water Resource System" (unpublished Ph.D. dissertation, Department of Civil Engineering, University of California, Los Angeles, 1962), 104p.; and Burt, op. cit.

3/ California Department of Water Resources, Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County: Appendix A, Ground Water Geology, Bulletin No. 104 (Sacramento, 1961), p. i.

4/ For geological phase, see ibid.; for hydrological phase, idem, Planned Utilization of the Ground Water Basins . . . Appendix B, Safe Yield Determinations, Bulletin No. 104 (Sacramento, 1962).

has not been completed, only preliminary information about the objectives and the method is available at this time.

The objective is to find the least-cost method of supplying water requirements, subject to the condition that the basin be protected from seawater intrusion.[1/] Since aqueducts are vulnerable to destruction by either natural or man-made disaster, maintenance of a reserve of potable water under the urbanized area is considered an essential security measure. The study does not include an attempt to find the optimum level of water development and use or the optimum allocation among various uses.

For efficient management of a groundwater basin, it is desirable to be able to predict the reaction to changes in the rate and distribution of replenishment or extractions. To analyze the flow characteristics of the coastal plain basins, the electronic analog method is being employed. The movement of water through a groundwater basin can be described mathematically, but the equations are extremely complex. Fortunately, the equations for the flow of electricity are sufficiently similar to those for the flow of groundwater to permit a solution by analogy.[2/] For analyzing the flow characteristics of the coastal plain, the area was divided in 82 unit areas, each represented by a control node in the analog model.

For the economic study, aggregations have been made to form 10 activity areas. Annual water requirements have been estimated for each area. Based on extensive information, including hydrologic data (storage capacity, transmissibility, and present water levels), and the costs of pumping groundwater, delivering surface water, recharging the basin, importing water from various sources, and constructing and operating saltwater barrier projects, the least-cost program for supplying projected water requirements and preventing seawater intrusion will be estimated. Numerous alternatives are being considered, each of which will prevent seawater intrusion, meet water requirements, and conserve local water. Each alternative is a different combination of pumping, recharging, and surface delivery rates; of pumping pattern; and of method of preventing seawater intrusion.

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1/ Discussion with Robert Y. D. Chun, Senior Engineer, Planning Branch, California Department of Water Resources, Los Angeles.

2/ Lloyd C. Fowler, "Electronic Analog Computers and Ground Water Basin Management," Proceedings: 1961 Biennial Conference on Ground Water Recharge, ed. Leonard Schiff (Fresno, California: Ground Water Recharge Laboratory, Soil and Water Conservation Research Division, 1962).

The Department of Water Resources has started a similar study of the San Gabriel Valley. Work is currently being done on the geological phase.

The Department has undertaken a tremendous task. While they are not likely to find a perfectly optimal program, a wealth of information on the costs of alternatives will be made available. This information can be utilized only when management is sufficiently integrated. However, by showing more clearly the potential savings, the investigation will provide an added incentive to make the necessary organizational changes.

Proposals for Supplying Water

In this section general plans for supplying water at minimum cost will be outlined. Alternatives considered will not be restricted to those applicable within the existing decision-making structure. Making tentative plans unrestrained by existing institutional limitations will focus attention on needed institutional changes.[1/]

As previously discussed, groundwater levels are low in Los Angeles County, existing import facilities do not have sufficient capacity to fill the basins, and water from northern California will be more expensive than Colorado River water. Hence, the supply from the Colorado River should be fully utilized both before and after the arrival of water from northern California.

Although there is no current shortage of water along the Colorado River, a recent Supreme Court decision has seriously jeopardized the future supply of the Metropolitan Water District. As diversions by other states increase, the Metropolitan Water District is likely to lose some if not all of its supply from the Colorado River unless the District can purchase water rights. The recent adjudication of rights to the lower Colorado River is of sufficient significance to justify some background discussion for the benefit of readers unfamiliar with the long struggle over rights to the Colorado River.

The Colorado River Compact of 1929 provides that the upper basin states (Colorado, New Mexico, Utah, and Wyoming) can deplete the average flow at Lee Ferry to 7,500,000 acre-feet per year; this is approximately one half of the natural undepleted average flow at that point. Below Lee Ferry, evaporation

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1/ Infra, pp. 55-85.

from reservoirs, natural river losses, regulatory waste, and the Mexican Treaty obligation require approximately 2,500,000 acre-feet per year. If and when the average flow at Lee Ferry is reduced to 7,500,000 acre-feet per year, the dependable supply from Lake Meade for use in the lower basin states (Arizona, California, and Nevada) will be approximately 5,000,000 acre-feet per year.[1/]

Arizona, California, and Nevada failed to agree on a division of their joint share. Much of the conflict centered on whether waters from tributaries entering the Colorado River in the lower basin were to be included in the division or left for the exclusive use of the state from which they entered. California claimed that water from these tributaries, most of which is from the Gila River in Arizona, should be included in the division. California maintained that this was the intent of the Colorado River Compact of 1929. Due to losses below Lee Ferry and the obligation to Mexico, the supply available for division within the lower area is approximately equal to that available to the upper area only if water from the lower tributaries is included in the joint supply of lower area.

The Court ruled that water from tributaries entering the Colorado River in the lower basin was not included in the waters to be divided but left for the exclusive use of each state.[2/] "The majority opinion said California was entitled to 4,400,000 acre-feet of water annually from the mainstream of the Colorado, Arizona 2,800,000 acre-feet, and Nevada 300,000 acre-feet."[3/]

These allocations total 7,500,000 acre-feet per year. If and when the average flow at Lee Ferry is reduced to 7,500,000 acre-feet per year, the supply for consumptive use in the lower basin will be only 5,000,000 acre-feet per year. If depletion in the upper basin continues to increase, California's share will eventually become substantially less than 4,400,000 acre-feet per year. The Court did not specify a formula for allocating water among states in periods of shortage. The power to make such allocations was left to the Secretary of the Interior.[4/] Within California, the Metropolitan Water District holds priorities to 1,212,000 acre-feet per year, but these priorities

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1/ Stetson, Strauss and Dresselhaus, Inc., op. cit., pp. II-18 through II-21.

2/ William M. Blair, "Arizona Upheld Over California on Water Rights," The New York Times, June 4, 1963, pp. 1 and 26.

3/ Ibid., p. 1.

4/ Ibid.

are junior to agricultural priorities totaling 3,850,000 acre-feet per year.[1/] Thus, the supply available to California must exceed 3,850,000 acre-feet for the Metropolitan Water District to be entitled to any water and must be 5,062,000 acre-feet for the District to receive its full supply.

It appears certain that the supply available to the Metropolitan Water District will eventually be reduced. The date of the first reduction and the subsequent rate of decrease in the supply will depend on future precipitation and the rate of increase in depletion by other states.

It must be emphasized that there is no current shortage of water along the Colorado River. The Metropolitan Water District can operate the aqueduct at full capacity so long as those with superior rights are not deprived of their supplies. Diversions by other states are not likely to become large enough to force reductions by the Metropolitan Water District before the middle of the 1970's.[2/]

The fact that the supply from the Colorado River is likely to be reduced in the future makes it particularly urgent that the aqueduct be operated at capacity while water is still available. The immediate problems are primarily those associated with achieving maximum utilization of existing import facilities to keep groundwater levels as high as possible. In the more distant future, a plan for filling vacant underground storage with water from northern California will have to be made, and the political and economic feasibility of purchasing additional rights to Colorado River water will have to be investigated.

Plans for the Immediate Future

Alternative ways of making maximum utilization of existing import facilities will be proposed for each basin. Alternatives considered will not be restricted to those applicable within the existing decision-making structure. Making tentative plans in this manner will focus attention on needed institutional changes.

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1/ Stetson, Strauss and Dresselhaus, Inc., op. cit., p. II-22.

2/ Idem, A Final Report on a Supplemental Water Supply for Upper San Gabriel Valley Water District (Los Angeles, 1962), p. 27.

San Fernando Valley.--If the bitter local conflict over water rights could be settled, groundwater stocks could be built up with existing physical facilities. Purchases of Colorado River water could be increased, allowing either reductions in groundwater extractions or groundwater replenishment with Owens River water. The problem here is entirely institutional; nothing can be accomplished until the dispute over groundwater rights is settled.

San Gabriel Valley.--Since groundwater rights have been adjudicated in the Raymond Basin and supplemental water is in use, the Raymond Basin area must be excluded from discussion of the remainder of the San Gabriel Valley. Metropolitan Water District feeder lines cross the main San Gabriel Valley, but this water is not available to the Valley at present because the area is not in the District. Supplemental water will be needed, particularly if the suit of the downstream pumpers is successful.

Previous to the formation of the Upper San Gabriel Valley Municipal Water District in 1960, some groups--believing they were more favorably situated--decided to form a separate district. Four cities formed the San Gabriel Valley Municipal Water District to avoid being included in the larger district.[1/] The San Gabriel Valley Municipal Water District has contracted with the state for water. With the continuing drought and the suit by downstream interests, their situation is no longer more favorable than that of the remainder of the Basin. If the suit by the lower area prevents them from meeting needs from groundwater stocks until water becomes available from northern California, they could begin taking Colorado River water immediately by joining the Metropolitan Water District and consigning their contract with the state to the District. As a possible alternative, interim needs might be met by reclaiming waste water either for their own use or for delivery to other areas in exchange for increased pumping rights.

The Upper San Gabriel Valley Municipal Water District is presently faced with the choice of annexing to the Metropolitan Water District or contracting with the state. Annexation would make Colorado River water available almost immediately. If they contracted with the state, interim needs would have to be met from groundwater stocks and reclamation of waste water. The sufficiency of these sources will depend on local precipitation during the coming

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1/ Statement by Carl Fossette in California Legislature, Assembly Interim Committee on Water, op. cit., pp. 130-131.

decade and on the results of the suit of the downstream pumpers against San Gabriel Valley pumpers.

Coastal Plain.--During 1960-61, water levels rose in the Montebello Forebay but continued to fall in the pressure area of Central Basin and in West Basin. Even with continued replenishment in the Forebay area, the planned 25-percent reduction in extractions from Central Basin can do little more than stabilize water levels in the pressure area. In view of the low water levels and seawater intrusion, it is particularly important for the coastal plain to build up water levels as much as possible while there is still some import capacity beyond that needed for supplying current demands. Due to the limited transmissibility capacity of the confined aquifers, it appears that this objective can be accomplished only if groundwater extractions from West Basin and the Central Basin pressure area are reduced to the lowest practical level. Groundwater should certainly not be pumped to supply demands that can be met with direct delivery of Colorado River water through installed connections. Additional connections should be installed where feasible. Joint management of Central Basin and West Basin appears necessary for achieving the needed reductions in pumping from the pressure area.

In analyzing the saltwater intrusion problems in West Basin and at Alamitos Gap, the Los Angeles County Flood Control District considered only three approaches: (1) allow the basins to be destroyed and supply the areas with surface deliveries, (2) reduce groundwater extractions enough to establish a seaward gradient, and (3) construct and operate barrier projects to protect the basins without any reduction in extractions.[1/] The first two alternatives were given only brief consideration before the third was chosen. They failed to consider what appears to be the most economical solution, that is, a combination of reduced pumpage and less expensive barrier projects. Failure to officially consider the suggested approach was not due to oversight on the part of the Flood Control District's staff. Since the Flood Control District has no jurisdiction over groundwater extractions, it cannot protect the basins with a program depending on reduced extractions. There is an urgent need for and integration of management to coordinate the rates and location of groundwater extractions with replenishment activities.

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1/ Los Angeles County Flood Control District, Report on Required Facilities. . . . Part I: . . . and Part II: . . . , pp. 73-74 and pp. 19-22, respectively.

The situation in the Montebello Forebay area is quite the reverse of that in the pressure areas. Transmissibility rates within the Forebay are sufficiently high to permit increased pumping provided enough water is available for replenishment.

If a settlement can be reached on the division of the natural waters of the San Gabriel River system between the upper and lower areas, the available water which cannot be spread in the Montebello Forebay can be stored in the San Gabriel Valley. The Central and West Basin Water Replenishment District has the authority to purchase water for storage outside the District. Water could be supplied from feeder lines which presently cross the San Gabriel Valley. Spreading in the upper part of the Basin would, after some delay, increase the quantity of water rising at Whittier Narrows.[1/] There is a possibility that spreading during the middle 1960's would be effective in increasing the flow to the coastal plain during the late 1960's and early 1970's when little, if any, water will be available for replenishment. The rate of flow would have to be investigated.

To fully utilize underground reservoirs, management will have to be integrated among basins as well as within basins. Organizational problems in coordinating the management of entire stream systems are discussed in a later section.[2/]

Plans for the More Distant Future

The Availability of Water.--For some years following the completion of the state aqueduct from northern California, import capacity will probably exceed demands for current use. Utilizing this "excess capacity" to build up groundwater reserves for subsequent use will postpone the need for future expansions in import facilities. The most economical schedule for filling vacant storage will depend on the rate of growth in demand for current use and on

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1/ The quantity of water rising at Whittier Narrows could be increased substantially without raising groundwater levels above previous natural levels. However, some recently constructed roads and buildings might be damaged by groundwater levels equal to former natural levels. The effects of raising water levels would have to be investigated.

2/ Infra, pp. 55-85.

the future availability of Colorado River water. The California Department of Water Resources in the current investigation of groundwater basin management is attempting to find the most economical schedule for filling vacant storage. Their calculations will, of course, have to be revised as additional information becomes available.

If there is no way for the Metropolitan Water District to obtain more secure rights to the Colorado River through court or congressional action, the possibility of purchasing rights should be investigated. Even with the cost of purchasing rights, importing Colorado River water through installed facilities might be less expensive than purchasing water from northern California. The Metropolitan Water District should investigate the feasibility of purchasing rights before the potential sellers install diversion and distribution facilities.

Advantages of Conjunctive Use Increase with Growth in Demand for Water.-- As the quantity of water used in Los Angeles County increases, local groundwater basins become relatively less important as natural sources of water and more important as reservoirs.

As the proportion supplied by importation increases, storage capacity (total ground and surface) will become smaller relative to annual use. Furthermore, the system planned by the state has less terminal storage in relation to the aqueduct capacity than do existing import facilities (Table 5). Since the better reservoir sites are developed first, construction of surface reservoirs is becoming more expensive through time.

Research by the Los Angeles County Flood Control District indicates that construction of tank storage in the service area costs approximately $16,300 per acre-foot of capacity.[1/] In the same report, data are cited showing that seasonal peaking from underlying or nearby groundwater basins is by far the most economical way of meeting seasonal peaks in demand.[2/]

With increased water use, more storage space will be needed for supplying seasonal peaks in demand. The entire storage and transmissibility capacities of the confined aquifers of the coastal plain may eventually be needed for seasonal peaking. Since water levels need to be kept fairly high in the Montebello

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1/ Los Angeles County Flood Control District, Report on Required Facilities. . . . Part I: . . . , pp. 97-101.

2/ Ibid.

TABLE 5

Comparison of Aqueduct and Terminal Storage Capacities
for Major Import Systems

System	Capacity of aqueduct	Terminal storage	Terminal storage capacity as a percent of aqueduct capacity
	acre-feet per year		percent
Los Angeles Aqueduct	289,518	95,391	32.9
Colorado River Aqueduct	1,212,000	219,200	18.1
State aqueduct to southern California	1,809,488	236,000	13.0

Sources:

Los Angeles Aqueduct: Vincent Ostrom, Water Supply (Los Angeles: The Hayes Foundation, 1953), pp. 12(a) and 17.

Colorado River Aqueduct: Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), pp. 9 and 43-44.

State aqueduct to southern California: Charles T. Main, Inc., Final Report, General Evaluation of the Proposed Program for Financing and Constructing the State Water Resources Development System of the State of California Department of Water Resources (Boston, 1960), pp. 4-5.

Forebay to maintain a flow into the pressure area, the coastal plain will likely become increasingly dependent on the San Gabriel Valley for cyclical storage.

The potential advantages of conjunctively utilizing local groundwater basins and import facilities are growing with increases in the quantity of water used. The potential returns to coordinating the management of basins along a stream system are also increasing. The following section will deal with the problems of integrating the management of ground and surface water and with the organizational problems of coordinating the management of an entire stream system.

INTEGRATING MANAGEMENT

Having reviewed past experience and outlined the potential role of groundwater basins in supplying future water needs, the study can now focus directly on integrating the management of ground and surface water.

Effective Group Action Necessary for Efficient Utilization of Resources

An individual water user can be expected to take the source least expensive to himself. In the study area, however, most final users are supplied by either a municipal water department or a public utility company; thus, the decision to pump groundwater or purchase imported water is generally made by water purveyors. Since rates to final users are based on costs, we might expect water purveyors to be more willing to purchase imported water to reduce an overdraft than an individual supplying water for his own use. However, from the analysis in a previous section, we must conclude that this has not been the case.[1/] The large overdraft and relatively small voluntary purchases of imported water indicate that cities and public utility companies have been primarily interested in keeping their costs and rates low.

On the other hand, some imported water has been purchased in the absence of pumping restrictions (Table 6). In all areas except Pasadena, Torrance,

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1/ Supra, pp. 8-18.

TABLE 6

Water Production and Imports of Constituent Areas of the Metropolitan Water District Located in Los Angeles County Fiscal Year 1960-61

Constituents	Local production[a]	Metropolitan Water District deliveries[b]	Other imports
	acre-feet		
Beverly Hills	7,866	3,548	0
Burbank	20,401	4,919	0
Central Basin Municipal Water District	208,619	9,978	0
Compton	7,541	359	0
Glendale	21,240	2,772	0
Long Beach	38,407	15,768	0
Los Angeles	107,137	106,606	316,637
Pasadena	13,085	21,518	0
Pomona Valley Municipal Water District	46,262	8,664	0
San Marino	5,590	10	0
Santa Monica	3,500	10,913	0
Torrance	2,418	14,373	0
West Basin Municipal Water District	77,275	72,495	0

a/ All local production is from groundwater basins except for occasional diversions of streamflow in a few areas.

b/ Metropolitan Water District of Southern California deliveries for direct use only.

Sources:

Metropolitan Water District of Southern California, Twenty-Third Annual Report (Los Angeles, 1961), 175p.

City of Los Angeles, Board of Water and Power Commissioners, Water and Power, 60th Annual Report, 1960-61 (Los Angeles, 1961).

and the West Basin Municipal Water District, the decision to pump or purchase was made on an individual basis.[1/] For several member areas, the distribution of purchases during the year indicates that the imported water was used primarily for supplying seasonal peaks in demand.[2/] Since the feeder lines and connections were installed, seasonal peaking with imported water was less expensive than maintaining standby pumping capacity. Voluntary purchases beyond that used for seasonal peaking reflect management's weighting of diverse and often conflicting goals. Water rights, overdraft, seawater intrusion, and public relations (as well as the relative costs) must be considered when choosing the relative rates of pumping and purchasing.

Individual persons, firms, and communities have generally acted primarily in their own interests rather than in those of the basin as a whole. The adjudication of Raymond Basin coordinated the interdependent interests and made management of the Basin possible. The hydrologic interdependence between Central Basin and West Basin has limited the success of adjudication in West Basin. The replenishment assessment levied on groundwater extractions by the Central and West Basin Water Replenishment District has somewhat reduced the individual incentive to pump. Progress toward more efficient utilization of groundwater resources and import facilities has been made only when effective group action has been taken to coordinate interdependent individual interests.

In summary, integrating the management of ground and surface water involves eliminating the rule of capture and establishing an organizational structure capable of coordinating the management of ground and surface water.

Control Over Groundwater Extractions

Collective control over groundwater extractions can be gained either by adjudicating rights or through economic incentives to individual users. The two approaches will be analyzed and compared.

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1/ During 1960-61, groundwater extractions were limited by adjudication for Pasadena and by interim agreement for Torrance and most of the major pumpers in the West Basin Municipal Water District.

2/ Metropolitan Water District of Southern California, Twenty-Third Annual Report, p. 45.

The Incentives of Prescription

The adjudication in Raymond Basin resolved the common use problem and stopped the uneconomic overdraft. Unfortunately, development of the prescriptive rights doctrine in that adjudication has intensified the problem of common use in other areas. In addition to the current economic incentive to take the less expensive groundwater, pumpers can now expect to be rewarded for increasing extractions from overdrawn basins and penalized for voluntarily purchasing imported water to lessen the overdraft.

A Legislative Attempt to Protect Those Willing to Purchase Imported Water.--The Water Code was amended in 1951 in an attempt to remove this additional incentive toward depletion.1/

> "Cessation of or reduction in the extraction of ground water, to permit the replenishment of such ground water by the use of water from an alternate nontributary source, is hereby declared to be a reasonable beneficial use of the ground water to the extent and in the amount that water from such alternate source is applied to beneficial use, not exceeding, however, the amount of such reduction."2/

The amendment applied only to the area within the counties of Santa Barbara, Ventura, Los Angeles, Orange, San Diego, Imperial, Riverside, and San Bernardino.

The act has not removed the incentives of prescription. Since credit for increases in purchases of imported water is allowed only to the extent of the reduction in groundwater extractions, little protection is provided in areas where water consumption is increasing. A pumper reducing extractions could only maintain his previously established prescriptive base, while one continuing to increase pumpage would increase his base. A subsequent adjudication defining the relative rights of pumpers and requiring a proportional reduction would reward those having continued to increase extractions. Furthermore, since the act has not been validated and interpreted by the courts, there is no certainty of even limited protection.

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1/ California, Water Code, Div. 2, secs. 1005.1 and 1005.2, c. 1.

2/ Ibid., Div. 2, sec. 1005.2.

Credit for Imports Under the Current Interim Agreement in Central Basin.--"Imported water use credit" is defined in the agreement to be ". . . the annual amount of imported water from sources nontributary to the Central Basin which any producer and any predecessors in interest have imported into the Central Basin and used beneficially in any water year since the calendar year 1951, in excess of the quantity of such water so imported and applied to beneficial use in the calendar year 1951 or any preceding calendar year."[1/] The assumed relative right of each pumper is calculated from the sum for each year of the imported water use credit and the quantity pumped.

Authors of the agreement were fully aware of the difference between the agreement and the Water Code (sections 1005.1 and 1005.2) with regard to credit for increased imports.[2/] Since water use in Central Basin had been increasing, the provisions of the Water Code gave little protection. The successful negotiation of the interim agreement indicates that most pumpers approve of crediting those who have supplied increases in demand by importation rather than by increased pumping. There is no way of knowing what credit, if any, will be given for increased importation in the final decision.

The race to build up rights is, of course, stopped by the initiation of court action to adjudicate rights. Control over extractions without adjudication depends on the removal of both the current economic incentive to pump and the incentive to build up rights for the future.

Adjudication

Record of Performance.--In the Raymond Basin case, which involved a relatively small area and only 31 parties, 8 years passed before pumping restrictions were placed on all parties, and 13 years passed before the final appeal was denied. In the West Coast Basin case, involving a larger area and 472 parties, 16 years were required to get a judgment defining the rights of all parties. As the case is being appealed, there is no way of knowing what the final decision will be or how much longer the case may take.

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1/ Central and West Basin Water Replenishment District v. Charles E. Adams et al., 786,656 Los Angeles (Calif.), Stipulation and Interim Agreement and Petition for Order (1962), p. 4.

2/ Interview with Max Bookman, December 4, 1962.

The total cost of these adjudications is open to considerable speculation. For each case, the costs include the expense of preparing the Report of Referee, general court costs, the fees of attorneys and consulting engineers, and the value of the time spent on the case by the parties and their employees. The cost of the Raymond Basin case to the City of Pasadena alone is estimated to have exceeded $1 million.[1/] As Pasadena was allotted 8,794 acre-feet per year, adjudication cost averaged more than $110 per acre-foot of annual right. Assuming an interest rate of 6 percent and assuming that Pasadena pumps 8,794 acre-feet per year forever without another adjudication, the cost of the adjudication will average approximately $6.60 per acre-foot pumped.

In the West Coast Basin case, the total expenses as of July, 1962, have been estimated to be in excess of $5 million.[2/] This averages more than $74 per acre-foot of "1949 prescriptive right" and more than $217 per acre-foot of average annual inflow during the period 1950-51 through 1955-56. There was no longer any significant flow into the Basin when the judgment was made in 1961.

It is significant to note that these adjudications would have taken longer and been even more expensive if in each case a substantial majority of the parties had not reached an agreement and signed a stipulation for judgment. Thus far, adjudication through the court reference procedure has not proven itself to be a practical approach to groundwater basin management. There are, however, a few encouraging factors. The Raymond Basin case was settled in spite of persistent opposition by one party. The cost of past adjudications may encourage agreement in future cases. With additional experience it may be possible to improve the court reference procedure.

Interim Agreements.--In both the West Coast Basin and Central Basin adjudications, pumpers representing a substantial majority of total groundwater production, through an interim agreement, voluntarily obligated themselves to reduce extractions during the remainder of the adjudication. Since those not signing the agreement are free to pump as much as they choose until restricted by the court and are not forced to reimburse those voluntarily agreeing to reduce pumpage, the success with which interim agreements have been negotiated

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1/ Blackburn, op. cit., p. 5.

2/ Statement by Rex B. Goodcell, Jr., in California Legislature, Assembly Interim Committee on Water, op. cit. (Long Beach, 1962), p. 78.

appears, at first glance, somewhat surprising. The explanation lies, at least to some extent, in the conditions under which these agreements were formed.

First, pumpers were not asked to restrict water use. Supplemental water was available, and each agreement provided for water rights exchange pools through which those without connections to imported supplies could purchase pumping rights.

Second, the areas involved were predominantly urban. An increase in water cost can be absorbed more easily by domestic and industrial users than by farmers using water for irrigation.

Third, there was a clear and urgent threat to the groundwater basins, this being seawater intrusion.

Fourth, no pumper claimed his right to be paramount to all others.

Fifth, there was face-to-face contact among major pumpers. Through the water associations and in meetings of the representatives of parties to the suits, there was ample opportunity for discussion and for developing a spirit of unity.

Under these conditions, pumpers were under considerable social pressure to participate in the interim agreement. Social pressure, created by these or similar conditions, is likely to be necessary to obtain participation in interim agreements.

When overdraft is resulting in seawater intrusion, the courts are authorized to control pumping during the adjudication by issuing a preliminary injunction. No preliminary injunctions have been issued. To date, the final judgments have not been sufficiently predictable to form a good basis for issuing a preliminary injunction. Furthermore, if an interim agreement can be negotiated with a high level of participation, its formation promotes further cooperation; whereas, a preliminary injunction would likely result in increased conflicts. However, if the interim agreement does not include all major pumpers, the noncooperators benefit from the reduction in pumpage by others and are likely to attempt to maintain the status quo by delaying the final settlement. With regard to encouraging agreement to stipulated judgment, an interim agreement is superior to a preliminary injunction if, and only if, a high degree of participation is obtained.

Stipulated Judgments.--In the Raymond Basin and West Coast Basin adjudications, most of the parties agreed to a stipulated judgment rather than to prolong the case in an effort to gain the greatest possible share of water. Parties to the current adjudication in Central Basin hope to reach agreement on all but a few issues which will be determined by the court.

Current negotiations in Central Basin: Having benefited from the experience of the two previous adjudications, parties to the current Central Basin case have been striving from the beginning to get agreement on as many issues as possible. The court will hear and decide only those questions on which no agreement can be reached.

There has been no petition requesting the court to appoint the State Water Rights Board as Referee. Physical facts are being compiled primarily by a private consulting firm, Bookman, Edmonston, and Gianelli, which has been doing most of the engineering for the Central and West Basin Water Replenishment District.

The report of an official referee becomes prima facie evidence; therefore, it must be prepared with great care and detail. Since a privately prepared report does not become prima facie evidence, detail of investigation into various questions can be more in proportion to their importance. Thus, the privately prepared report can be compiled more quickly and at smaller cost.

Should the parties fail to accept the results of the investigation by Bookman, Edmonston, and Gianelli, the adjudication will likely be longer and more expensive than if the court reference procedure had been used. However, the success with which the interim agreement was negotiated indicates that most of the parties are seeking a solution and will likely agree to a stipulated judgment.

Current negotiations between Central Basin and the San Gabriel Valley: The suit to limit pumping in the San Gabriel Valley is also a civil suit without reference to the State Water Rights Board for a Report of Referee. The parties are attempting to avoid the costs of a complete litigation by negotiating an agreement. As with the suit in Central Basin, if no agreement is reached, the adjudication will likely be longer and more expensive than if the court reference procedure had been used. Since limiting extractions from the San Gabriel Valley is primarily for the benefit of Central Basin pumpers,

negotiating an agreement will probably be more difficult than in the suit within Central Basin.

Opportunities and limitations: The conditions previously described as conducive to the formation of an interim agreement are also favorable to the negotiation of an agreement to a proposed judgment. As compared to an interim agreement, the permanency of the stipulated judgment may encourage pumpers to be more cautious. Other factors tend to make agreement to a stipulated judgment easier than to an interim agreement. Those refusing to sign an interim agreement can do so without taking any positive action; whereas, those disagreeing with a proposed judgment force the issue into court, thereby increasing the costs of adjudication to themselves as well as to others.

On the other hand, the costs of additional litigation can become a bargaining tool for an individual who, in an effort to obtain additional water, may object to some portion of a proposed judgment. While it might be less expensive for the other parties to make a concession than to litigate the issue, concessions to individuals should be avoided as they will encourage others to make similar demands.

The importance of agreement on as many issues as possible cannot be overemphasized; however, in some cases agreement may be impossible and complete litigation may be necessary. Continued efforts should be made to improve adjudication procedures. Furthermore, reducing the time and expense required for adjudicating rights reduces the bargaining power of those refusing to agree in an effort to obtain a concession. Fortunately, successful litigation of one case encourages agreement without litigation in subsequent cases. As more cases are litigated, more precedent is established making the action of the court more predictable.

Reflection on Possible Improvements in Adjudication Procedure.--Several modifications in the adjudication procedure may help to overcome some of the difficulties discussed above.

Reduce number of parties: The Raymond Basin case included only those pumping 25 acre-feet or more per year. The West Coast Basin adjudication included all pumpers.[1/] Considering the value of groundwater in southern

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1/ J. Herbert Snyder has suggested that exempting parties pumping less than 25 acre-feet per year would not have significantly altered the results of the adjudication; see Snyder, "Economic Implications and Appraisal . . . ," p. 64.

California, 25-acre feet appears to be a rather large minimum. Ten acre-feet is proposed to be a reasonable compromise.[1/] In the West Coast Basin case, exempting those with prescriptive rights of less than 10 acre-feet would have reduced the number of parties from 472 to 151.[2/] The 321 parties with individual rights of less than 10 acre-feet have a total right of only 528.4 acre-feet or .78 percent of the Basin total.

If the small producers were exempted and each began pumping the full 10 acre-feet per year, the total would be significant. This theoretical possibility is of little practical importance, because there is no reason to believe that those choosing to pump 1 acre-foot before the adjudication would suddenly begin pumping 10 acre-feet per year. If a pumper originally exempted began pumping more than the allowable maximum for exempted producers, court action could be taken against him just as action would have to be taken to stop anyone who began pumping without a right. By exempting small producers, the time and expense of an adjudication can be reduced without significantly affecting the results.

Greater utilization of the Recordation Act: In the West Basin adjudication, considerable time and expense were necessary for compiling a complete list of pumpers. In the counties of Riverside, San Bernardino, Los Angeles, and Ventura, the names of those pumping more than 25 acre-feet per year are

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1/ The annual cost to the other pumpers of leaving out a small producer can be estimated in the following manner: annual unrestricted pumpage x percentage reduction required of parties to the adjudication x the value of the right to pump an acre-foot of water. Pumpage was reduced by 25 percent in West Basin and the right to pump 1 acre-foot is worth approximately $19. (Sales through the West Basin exchange pool were at $19 per acre-foot during fiscal year 1960-61.) Considering the possible minimums of 25 and 10 acre-feet per year:

25 acre-feet per year x .25 x $19 per acre foot = $118.75 per year.

10 acre-feet per year x .25 x $19 per acre-foot = $47.50 per year.

The stream of annual costs of leaving a small pumper out of the adjudication must be weighted against the cost of including him. It is beyond the scope of this study to attempt to estimate the increase in cost (and time) resulting from the inclusion of one or more small pumpers in an adjudication. For the rest of the analysis, 10 acre-feet is assumed to be a reasonable minimum; see California Department of Water Resources, Report on Watermaster Service . . . July 1, 1960 through May 31, 1961, p. 25.

2/ Snyder, "Economic Implications and Appraisal . . . ," p. 65.

readily available from filings under the Water Recordation Act of 1955.[1/] As no prescriptive rights can accrue to those failing to file, the list should be complete.[2/] If those pumping less than 10 acre-feet per year are to be excluded from the adjudication, the problem of identifying parties would be solved if the Water Code were amended to require reports of extractions from all persons pumping 10 acre-feet or more per year.

The Water Recordation Act provides that filings are not admissible court evidence.[3/] It has been proposed that they should be made admissible.[4/] Since a pumper has an incentive to report more than he pumped, these filings are of limited value as evidence until they are checked and validated by either the State Water Rights Board or the court. The potential use of unvalidated filings is discussed below.

It has been proposed that legislative action is needed to facilitate the issuance of preliminary injunctions to prevent increases in pumping or, in some cases, to restrict pumping during the remainder of the adjudication.[5/] Opponents of such legislation note that preliminary injunctions can be issued under existing law and warn that easily obtainable preliminary injunctions could permanently impair the economic growth of an area.[6/] This objection would be of great importance in the absence of a supplemental supply; however, the adjudications to date have involved only the rationing of a less expensive supply and have not forced reductions in water use. Where a supplemental supply is available, unvalidated filings under the Water Recordation Act appear to be adequate evidence for issuing a preliminary injunction, provided that provisions are made for injured parties to be reimbursed after a final judgment based on validated records is made. The Water Code should be amended to permit this limited use of unvalidated records.

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1/ California, Water Code, Div. 2, Part 5, secs. 4999-5008.

2/ Ibid., Div. 2, sec. 5003.

3/ Ibid., Div. 2, sec. 5007.

4/ Statement by James H. Krieger in California Legislature, Assembly Interim Committee on Water, op. cit. (Long Beach, 1962), p. 14.

5/ Ibid., pp. 12-13; also statement by Rex B. Goodcell, Jr., in ibid., pp. 68-69.

6/ Statement by Ralph B. Helm in ibid., pp. 50-52.

Statutory procedures: There have been several proposals that adjudication of groundwater rights would be facilitated by the establishment of a statutory procedure similar to that presently in effect for adjudicating rights to surface water.[1/] This issue was discussed at length at the hearing held by the Assembly Interim Committee on Water in Long Beach. No consensus of opinion was reached.[2/] To date it has not been clearly demonstrated that moving to a statutory procedure would significantly reduce either the time or the expense required for an adjudication.

Outlook for procedural improvements: Adjudication can, no doubt, be facilitated by procedural improvements. Time and expense would be saved by excluding from the adjudication those pumping less than 10 acre-feet per year. Amending the Water Recordation Act to require reports of extractions from those pumping as much as 10 acre-feet per year would provide identification of parties. Another amendment to the Water Code allowing the use of unvalidated Water Recordation Act filings in a preliminary judgment, provided supplemental water is available and provisions are made for injured parties to be reimbursed after a final judgment based on validated records is made, would make control over pumping possible during the remainder of the proceedings.

With additional experience in the adjudication of groundwater rights, procedural improvements will be found. However, we must not delude ourselves into unrealistic expectations. Considering the legal uncertainties, the impossibility of defining the exact boundaries of groundwater basins, the great number of parties involved, and the ease with which records of history of use of individual pumpers can be challenged, there seems to be no possibility of developing a procedure capable of adjudicating rights quickly and at small costs unless the parties can reach agreements on a substantial number of issues.

Collective Control Over Pumping Through Economic Incentives

Groundwater basins can be effectively managed without adjudicating individual rights if collective control over pumping can be exercised through economic incentives to individual pumpers. Provided the incentive to build

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1/ Ibid.

2/ For information on the existing statutory procedure for adjudicating rights to surface water, see California, Water Code, Div. 2, secs. 2500-2900.

up water rights though increased pumping is removed, an individual can be expected to voluntarily shift from ground to surface water if surface water is made available at a price lower than the variable cost of extracting groundwater. Due to differences in pumping lift; power rates; and size, type, and age of pump, the variable cost of pumping varies significantly within a basin. Since pumping costs vary among pumpers, small changes in the price of surface water or in the rate of assessing groundwater extractions do not result in sudden shifts between ground and surface water. With sufficient institutional flexibility, the desired rate of pumping can be achieved by adjusting the price of surface water and the pumping assessment rate on a trial-and-error basis.

The local public district can provide the organizational structure for group action. The existing Water Replenishment District Act authorizes most of the powers necessary for groundwater basin management based on economic control over extractions.

After discussing ways of altering current economic incentives, a proposal will be made for eliminating the incentive to build up rights for the future.

Alternative Approaches.--Since importation costs are commonly met from both water sales and property assessments, an integrating agency supplying surface water can discourage or encourage pumping simply by pricing the surface water slightly below or above the variable costs of pumping. This approach is commonly used by irrigation districts in the San Joaquin Valley.[1/]

Where the integrating agency does not supply the surface water, it can encourage a reduction of groundwater extractions by paying a portion of the import cost. Since the early 1930's, the Santa Clara Valley Water Conservation District has been capturing local flood waters for groundwater replenishment. The expenses have been met by an ad valorem property tax. The replenishment program has not been sufficient to prevent falling water levels. In an effort to reduce extractions, the District has agreed to assist four cities in purchasing part of their supply from the City of San Francisco. In a contract with the City of Sunnyvale, the District has agreed to contribute $20 toward the cost of each acre-foot purchased.[2/] After the District begins importing water from

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1/ Michael F. Brewer, Water Pricing and Allocation with Particular Reference to California Irrigation Districts, University of California, Giannini Foundation Mimeographed Report No. 235 (Berkeley, 1960), pp. 94-96.

2/ Unpublished contract between the City of Sunnyvale and the Santa Clara Valley Water Conservation District, signed May 23, 1961, p. 2.

the Central Valley, the rate of payment to Sunnyvale will equal the cost per acre-foot to the District of importing water for replenishment. Adjustments will be made to make the total payments equal to what they would have been if the latter rate had been in effect since the beginning of the contract. Similar agreements have been made with the other three cities. Even with this arrangement, the imported water costs the cities more than the variable cost of pumping; however, the differential is sufficiently reduced to secure their cooperation in reducing the draft on the basin.

The Central and West Basin Water Replenishment District is authorized to pay from District funds a portion of the cost of water from a nontributary source where such payments will encourage the purchase and use of such water in lieu of pumping groundwater.[1/] The District has not exercised this power.

The other approach to economic control is, of course, through increasing the variable cost of using groundwater by levying an assessment on groundwater extractions. The Water Replenishment District Act and the Orange County Water District Act provide for the assessment of groundwater extractions; however, both enabling acts specify that the assessment is to be set in accordance with replenishment needs.[2/] The pumping assessment is viewed as an equitable way of distributing the cost (or at least part of the cost) of purchasing water for replenishment. Nevertheless, the pumping assessment could be used in controlling extractions provided the provisions of the enabling acts were not violated.

Economic control over pumping may often involve both pricing surface water lower than importation cost and taxing groundwater extractions. The price of surface water, the pumping assessment rate, and the rate of assessment on property value must be set simultaneously.

Pumping Assessments Essential to Management Based on Economic Control.-- The taxation of groundwater extraction is an essential tool of economic control and holds implications for both equity and economic efficiency.

Equity and political considerations: The development of a dependable water supply increases property values; thus, property owners receive benefits

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1/ California, Water Code, Div. 18, sec. 60230.

2/ Ibid., Div. 18, secs. 60300-60317; also, California, Statutes, "Orange County Water District Act, As Amended," pp. 16-17. (Reprinted by Orange County Water District, Santa Ana, California, September, 1961.)

not necessarily related to the quantity of water used on their property. Recovering at least a portion of the cost of constructing facilities through assessment of property values appears equitable and has generally been politically acceptable.[1/] However, continually recovering most of the importation cost from assessments on property values is sure to encounter strong opposition.

Until the last few years, the demand for Colorado River water was so low that regardless of pricing policy there was no way for the Metropolitan Water District to collect from water sales a very significant portion of expenses. Since variable costs were low, the District set prices to sell as much as possible. Over time, rising demand for water has resulted in increased sales even though prices have been raised. Revenues from water sales have been rising rapidly; however, in the fiscal year ending June 30, 1961, receipts from water sales were only $15,421,182, while taxes received from member agencies totaled $27,853,921.[2/] The present policy of the Board of Directors is to continually shift the cost from taxpayers to water users.[3/] The Metropolitan Water District levies taxes in proportion to the assessed value of property within member agencies. The member agencies can raise funds as they choose. Most member agencies tax property to meet this obligation.

Assessments by members of the Metropolitan Water District are not the only property taxes directly associated with water importation. The Los Angeles County Flood Control District levies taxes to cover the costs of spreading Colorado River water and of constructing and operating saltwater barrier projects. Zones I and II of the Flood Control District tax property to purchase water for spreading and injecting and to pay part of the cost of constructing barrier projects. The Central and West Basin Water Replenishment District levies a small property tax to cover operating expenses exclusive of water purchases. The petition to form the Replenishment District limited the power to tax property to that sufficient to cover operating expenses.

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1/ For additional discussion, see Brewer, op. cit.; particularly pp. 122-132.

2/ Metropolitan Water District of Southern California, Twenty-Third Annual Report, p. 156.

3/ Interview with Warren Butler, member of the Board of Directors, Metropolitan Water District of Southern California.

A large portion of water importation costs are already being paid from property taxes. Furthermore, the trends appear to be in the direction of decreasing taxes for water importation and of increasing water prices. Economic control over pumping without an assessment on groundwater extractions does not appear politically possible.

Relation to resource allocation: At this point, the analysis comes in contact with the whole array of problems dealing with the determination of the proper level of water development and use and of the best allocation of water among uses and among users. Extremely divergent points of view of these problems are represented in the literature on water development. Much planning is based on projections of water requirements with no consideration for any relation between the price of water and the quantity used. The fallacies of such projections have been discussed elsewhere.[1/] At the other extreme, we find many economists concentrating on the calculation of quantitative optima in water development and allocation. The limitations of such calculations were discussed previously.[2/]

For stringently defined theoretical conditions, conventional economic theory demonstrates that resources are most efficiently allocated when sold at a price equal to the marginal cost of production. The basic assumptions of this theoretical model include perfect competition throughout the economy, perfect knowledge and foresight, complete divisibility of all resources and products, and transmission of all economic forces through the marketplace. These deductions are not directly applicable to water pricing but are helpful in establishing guidelines.[3/]

For the purpose of this study, it is important to recognize that water needs are relative and that the quantity used depends, at least to some extent, on the cost to the user. Pricing imported water equal to the variable cost of pumping groundwater encourages water use in excess of that commensurate with

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1/ Ciriacy-Wantrup, "Projections of Water Requirements in the Economics of Water Policy," Journal of Farm Economics, Vol. 43, No. 2 (May, 1961), pp. 197-214. (University of California, Giannini Foundation Paper 193.)

2/ Supra, pp. 41-55.

3/ For a discussion of the relevance of welfare economics to water pricing and additional references on the subject, see Brewer, Economics of Public Water Pricing, University of California, Giannini Foundation Research Report No. 244 (Berkeley, 1961), pp. 12-15.

the cost of importing supplemental water. Assessment of groundwater extractions must be an integral part of integrated management based on economic control over pumping.

Must Also Remove the Incentives of Prescription.--Pumpers will likely make voluntary reductions in extractions only if they expect the cost equalization policy to be permanent. Should the policy be abandoned and groundwater rights adjudicated, those having continued to pump would gain an advantage unless provisions are made for protecting those shifting to surface delivery.

The Water Replenishment District Act provides that ". . . in the event of an adjudication of all or substantially all of the rights to extract groundwater and a determination of the natural safe yield of the groundwater supplies within the district, . . . the board of such district shall recognize such judicial determination by exempting from replenishment assessments the amount of water pumped by each person whose rights have been so adjudicated which does not exceed his proportionate share of the natural safe yield of the ground water supplies of the district. . . ."[1/] In view of the present water levels and continuing seawater intrusion into both Central and West Basins, it does not appear that there is any natural safe yield within the Central and West Basin Water Replenishment District; therefore, it is not likely that any exemptions will be allowed in the near future. If water levels rise enough to remove the danger of seawater intrusion, pumpers will probably be allowed to extract their share of the natural inflow free from assessment.[2/] The possibility of future exemptions encouraged pumpers in Central Basin to build up their prescriptive base in preparation for the coming adjudication.

The Orange County Water District Act provides for assessment of all groundwater extractions within the District.[3/] The District is not authorized to initiate an adjudication. Even if rights are adjudicated on the initiative of an individual pumper, the Orange County Water District is not

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1/ California, Water Code, Div. 18, sec. 60350.

2/ While protection from seawater intrusion by a freshwater pressure mound would allow a basin to have a safe yield even though water levels were below sea level, natural inflow under such conditions would not be a completely natural safe yield.

3/ California, Statutes, "Orange County . . . ," pp. 18-21.

obligated to exempt adjudicated shares of the natural safe yield from the pumping assessment. Although the Orange County Water District has not actually adopted a cost equalization policy, the cost differential has been reduced by the pumping assessment.

During 1961-62, the pumping assessment was $5.50 per acre-foot in the Orange County Water District[1/] as compared to $5.75 in the Central and West Basin Water Replenishment District.[2/] During the same year, water users in the Orange County Municipal Water District took 21.3 percent of their total supply as direct deliveries from the Metropolitan Water District as compared to 4.6 percent taken by the Central Basin Municipal Water District.[3/]

The Water Replenishment District Act could be amended to allow new districts formed under the Act to eliminate the incentive to build up rights for the future. An amendment could allow a choice to be made between two plans at the time of formation. One plan would give the district the power to initiate an adjudication and would require that adjudicated shares of natural safe yield be exempted from replenishment assessments in the event of the adjudication of all or substantially all of the rights to the basin's natural safe yield. The alternate plan would not give the district power to initiate an adjudication and would not provide for exempting any extractions from the replenishment assessment. This would allow a choice between management with adjudication and management with economic control over pumping.

Adjudication and Economic Control Compared

In a recent article on groundwater basin management, it was concluded that conflicts between basins along a stream system (over local groundwater) would likely prevent economic regulation without adjudication from being permanently satisfactory except in the last basin along the stream.[4/] Problems

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1/ Statement by Howard W. Crooke in California Legislature, Assembly Interim Committee on Water, op. cit. (Anaheim, 1961), p. 52.

2/ Ground Water Problems in California, A Report of the Assembly Interim Committee on Water, Vol. 26, No. 4, 1961-1963, p. 24.

3/ Metropolitan Water District of Southern California, Twenty-Third Annual Report, p. 50.

4/ Krieger and Banks, op. cit., p. 69.

of coordinating the management of basins along a stream system will be discussed.[1/] The following analysis deals with management within a single management unit which could be either an entire stream system or a single basin with a defined share of the stream's natural yield.

Adjudication and economic control will be compared with regard to convenience in integrating management of ground and surface water, effect on efficiency of resource allocation, and distribution of benefits.

Relative Convenience in Integrating Management of Ground and Surface Water.--The decision to adjudicate rights in Central Basin has already been made, and it is highly unlikely that the proceedings will be dropped in favor of economic control over pumping. However, since the reader is acquainted with the variety of challenging problems in Central Basin, the relative convenience of the two approaches will be compared in relation to these problems.

It was previously concluded that extractions from the Central Basin pressure area should be made only to meet those demands which cannot be supplied through existing feeder lines.

Vacant storage in the Montebello Forebay will be filled by June, 1964, if replenishment is continued as planned.[2/] From that time through 1967, and possibly longer, more water will be available for replenishment than can be spread. As long as the Forebay can be kept full with water purchased at the replenishment rate, there is no need to reduce extractions. Since the Metropolitan Water District sells water at the replenishment rate only when water can be delivered in addition to deliveries for direct use, Central Basin may not be able to purchase Colorado River water at the replenishment rate after 1967 or 1968.

If the adjudication proceedings were dropped and a permanent policy of economic control adopted, there would probably be no difficulty in soliciting sufficient cooperation to get the needed reductions in extractions from the pressure area. The pumping assessment rate needed to achieve the desired reduction in extractions could be estimated from data on pumping costs and surface water prices. As the pumping assessment would have to be periodically adjusted

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1/ Infra, pp. 85-86.

2/ Los Angeles County Flood Control District, Report on Required Facilities. . . . Part I: . . . , p. 42.

in response to changing prices and groundwater levels, there would be no need for extensive research in making the original estimate.

Since pumping lifts are greater in the pressure area than in the Forebay, an assessment rate could be chosen which would encourage a shift to surface water in the pressure area but would not encourage such a shift for most of those pumping from the Forebay. With future decreases in the quantity of Colorado River water available for purchase at the replenishment rate, the pumping assessment rate could be increased to encourage a reduction in extractions from the Forebay as well as from the pressure area.

The Metropolitan Water District is currently selling softened water for normal use at $29.00 per acre-foot and unsoftened water for replenishment at $14.25. Variable pumping costs are probably no more than $8.00 per acre-foot for most pumpers. A pumping assessment of $21 per acre-foot on total pumpage (of natural and imported origin) would obviously produce a considerable surplus. Revenue from the pumping assessment could be used to pay part of the cost of direct deliveries.

There are at least three possible variations of management with adjudication. Rights can be adjudicated in terms of the average yield from both natural and imported origin. Since economic control over extractions would not be needed, a pumping assessment could be levied solely for financing the replenishment program. There would be no need to adjust the price of direct deliveries.

Another approach is to adjudicate rights to the natural yield. The increase in yield resulting from replenishment could be allocated in proportion to rights to natural yield. Extractions of the replenishment yield could then be assessed at a rate equal to the cost per acre-foot of replenishment; or the increase in yield resulting from replenishment could be allocated on a cost-equalization basis. Since the latter would probably involve a pumping assessment greater than the cost per acre-foot of replenishment, a portion of the revenue would be available for paying part of the cost of direct deliveries.

With a uniform price for surface water, pumping rights would have greater value in the areas with smaller pumping lifts. In the case of Central Basin, there would be an incentive to change the pumping pattern in the desired direction.

In regard to convenience in integrating the management of ground and surface water in Central Basin, there appears to be no easily discernible difference

between management with adjudication and management with economic control over pumping. As Central Basin has a variety of problems associated with overdraft, limited transmissibility rates, and seawater intrusion, either approach should be effective in basins having only some of these problems.

Relative Effects on Efficiency of Resource Allocation.--With due regard for the glaring disparities between the assumptions of welfare economics and the current economic environment of Los Angeles County, there seems to be some merit in having the marginal cost (or the marginal opportunity cost) of water to the individual user approximately equal to the marginal cost of importing water. This is accomplished if groundwater rights are adjudicated and surface water is priced equal to the marginal importation cost. When quantitatively defined, and made transferable, the pumping right has an annual market value equal to the amount by which the price of surface water exceeds the variable pumping cost. The opportunity cost of using groundwater is, therefore, made equal to the cost of surface water.

Management through economic control equalizes the marginal cost of ground and surface water and equalizes the marginal cost of water to each user. However, for the same division of importation cost between property owners and water users, the marginal cost would be small if a large proportion of the supply is imported. The effect on resource allocation would depend on both the amount of the underpricing and the elasticity of demand for water.

Efficient allocation of water through time depends on reallocations in response to changing conditions.[1/] If adjudication is accompanied by a groundwater rights exchange pool, as it has been in previous adjudications, neither adjudication nor economic control obstructs reallocation among uses and among users.

While provisions for reallocation are necessary, water users can make long-range plans and investments only if they are sure of having a continuing water supply and have some protection against large, unexpected increases in water cost. Judging from past experience, there is little danger of an actual water shortage in the urban areas of Los Angeles County, except that which might result from a major disaster. At any rate, the alternatives being compared are

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1/ For a discussion of flexibility and security as economic criteria for evaluating a system of water rights, see Ciriacy-Wantrup, "Concepts Used As Economic Criteria for a System of Water Rights," Land Economics, Vol. XXXII, No. 4 (November, 1956), pp. 295-312.

indifferent in regard to protection against physical shortage. The two approaches are different with respect to protection against sudden increases in water cost. With adjudication, those having established rights are assured of a limited supply at low cost. The cost of water in excess of adjudicated shares and of all water for new users will depend on future importation cost. With a cost-equalization policy, the cost of all water to all users will increase with increases in importation cost; but, due to the averaging with the cost of local water, the cost to users will not rise as rapidly as importation cost. Adjudication provides more security for those with established rights but creates increased uncertainty for new users.

Relative Distribution of Benefits.--If rights are adjudicated, the flow of benefits from the basin's natural yield is distributed in proportion to established prescriptive rights. If a basin is managed through economic incentives, this flow is distributed in proportion to current water use. An individual must increase water usage at the same rate as the rate of increase for the basin in order to maintain his original share of the benefits from the natural yield.

Assume, for example, that total water use in a basin increases at a rate 4 percent per year faster than the rate of increase for a particular individual. For this person, the value per acre-foot of adjudicating rights would be equal to the present value of future benefits with an adjudication less the present value of future benefits with a cost equalization policy. For example, assume that 1 acre-foot of natural yield is worth $20 per year. Assume an interest rate of 6 percent per year. The present value of future benefits with an adjudication is $333.33 per acre-foot as compared to $192 without an adjudication.[1/] For an individual with water use increasing at a rate of 4 percent per year less than the rate of growth for the basin, an adjudication would be worth $141.33 per acre-foot. For an individual being outgrown at a rate of 2 percent per year, the comparable figure would be $88.33.

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1/ Present value of future benefits if rights are adjudicated = $\frac{\$20.00}{.06}$ = $333.33.

(Footnote continued on next page.)

Conclusion.--With regard to convenience in integrating management and to efficiency of resource allocation, there appears to be no significant difference between management with adjudication and management through economic control. There is a major difference with regard to the distribution of benefits from the natural yield of the underlying basin, particularly if some parties are rapidly increasing water use and others are not. The question of which of these distributions is the more equitable is beyond the scope of this study.

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(Footnote 1 continued.)

Calculation of present value of future benefits if rights are not adjudicated:

Year	Price	Quantity in acre-feet	Discount factor	Present value
1	\$20	.96	$\frac{1}{(1 + .06)}$	$\frac{\$20\ (.96)}{(1 + .06)}$
2	\$20	$.96^2$	$\frac{1}{(1 + .06)^2}$	$\frac{\$20\ (.96)^2}{(1 + .06)^2}$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
i	\$20	$.96^i$	$\frac{1}{(1 + .06)^i}$	$\frac{\$20\ (.96)^i}{(1 + .06)^i}$

Let PV represent the sum of present values for all years, one through infinity.

$$PV = \sum_{i=1}^{\infty} \frac{\$20\ (.96)^i}{(1 + .06)^i} = \sum_{i=1}^{\infty} \$20 \left(\frac{.96}{1.06}\right)^i = \$20 = \sum_{i=1}^{\infty} .90566^i$$

Let .90566 be represented by c.

$$PV = \$20 \sum_{i=1}^{\infty} c^i = \$20 \left[c^1 + c^2 \ldots \text{(to infinity)}\right].$$

$$= \$20 \left[1 + c^1 + c^2 \ldots \text{(to infinity)} - 1\right].$$

$$= \$20 \left[\frac{1}{1 - c} - 1\right] = \$20 \left[\frac{1}{1 - .90566} - 1\right].$$

PV = \$192.00.

The success of either approach depends on cooperation and compromise. If pumpers can agree to a stipulated judgment without years of litigation, individual rights can be defined without undue expense. The decision to form a district with sufficient powers to exercise economic control over groundwater extractions must be made by the voters. However, municipal water departments, public utility companies, and large private users must provide the leadership in forming and managing such a district. If neither agreement to a stipulated judgment nor formation of a public district with economic control over pumping is possible, the management of ground and surface water can be integrated only after individual rights are adjudicated. Every effort should be made to improve adjudication procedures as well as to encourage agreement and compromise.

Organizational Structure

The necessity of group control over groundwater extractions for the joint utilization of groundwater basins and imported supplies has been emphasized, and alternative methods of establishing this group control have been analyzed. Attention can now be focused on the equally essential task of forming an organizational structure through which the many interrelated aspects of supplying water can be coordinated.

The number of public and private agencies involved in supplying water in Los Angeles County is tremendous. Interrelated functions are being performed by the Metropolitan Water District; the Los Angeles County Flood Control District and the assessment zones within the District; the Central and West Basin Water Replenishment District; several municipal water districts; and numerous municipal water departments, public utility companies, and individual pumpers.

Integrating the management of related functions will be referred to as vertical integration, and integrating the management of related areas will be referred to as horizontal integration. As the analysis proceeds, it will be increasingly evident that the vertical and horizontal dimensions of integrating management are more clearly divided in theory than in practice. The management of related functions and of related areas must often be integrated simultaneously.

Vertical Integration

Consolidation of Functions Within a Single Agency.--At first glance, it appears that many problems could be solved rather simply by having a single agency or district perform all aspects of water supply within a hydrologic unit. However, only a brief analysis is needed to reveal serious limitations in both the formation and management of such a master district.

The most feasible importation unit often includes several hydrologic units. Since the southern California coastal region is the most feasible unit for importing Colorado River water, an agency in which all related functions could be consolidated would have to include this entire region. The political objections and administrative complexities of consolidating all aspects of water supply, including municipal distribution, in an agency of this size are rather obvious. Furthermore, with the development of the State Water Plan, complete consolidation would mean state performance of local functions. It must be concluded that complete consolidation of all related functions is not feasible.

Even assuming that import facilities are to be constructed and operated by a larger unit, complete consolidation of all other water supply functions for one drainage system or even for one groundwater basin does not appear practical. Where water is being supplied by a complex of private and public agencies, consolidating the management of the related functions into a single agency, if possible at all, would take years of negotiations.

Cooperation Among Existing Agencies.--In Los Angeles County, agencies originally formed to develop and distribute local water have had limited success in integrating the management of local and imported supplies without significantly altering the organizational structure. In Raymond Basin, integration has been achieved through the courts. In the coastal plain, some cooperation among previously organized agencies has been possible, but most of the progress appears to have been made through the courts and the recently formed Central and West Basin Water Replenishment District.

The Orange County Water District, which was organized long before imported water became available in Orange County, has made considerable progress in integrating the management of local and imported supplies. However, this expansion in the District's functions was made possible by the amendments authorizing the District to levy assessments on groundwater extractions and property values for the purpose of purchasing imported water for replenishment.

In summary, it appears that agencies organized to develop and distribute local water cannot cooperatively integrate the management of ground and surface water in relation to water importation without the help of either the courts, a new agency, or an old agency with greatly expanded power.

Coordination Through an Overlying District.--Formation of an overlying district with broad powers as authorized by the Water Replenishment District Act appears to be the most feasible approach to integrating the management of ground and surface water.[1/] A coordinating agency needs the flexibility provided by broad powers; however, extreme caution must be exercised to avoid unnecessary duplication of facilities and services already available through existing agencies. The enabling act specifically instructs replenishment districts to contract with existing agencies for the use of their facilities where such contracts can accomplish the purposes of the district more economically than by direct performance by the district.[2/]

The Central and West Basin Water Replenishment District has made considerable progress without constructing any physical facilities. Imported water purchased by the Replenishment District is spread and injected by the Los Angeles County Flood Control District without charge. The reclamation plant at Whittier Narrows is undoubtedly a milestone in interagency cooperation. The county furnished the capital to build the plant, the Sanitation District built and operates the plant, and the Replenishment District purchases the water, which is then spread by the Flood Control District at its own expense.

Thus far, the Central and West Basin Water Replenishment District has avoided duplicating existing facilities and services. The success of an overlying district will depend to a great extent on its avoiding unnecessary expansion of facilities.

Horizontal Integration

While the groundwater basin appears to be the smallest feasible management unit, a larger unit may often be desirable. Nearby hill areas receiving water from a basin should, of course, be included in the management unit.

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1/ Recall the earlier conclusion that management through the courts does not facilitate full utilization of a basin's storage potential, particularly with regard to the staging of expansions in import facilities.

2/ California, Water Code, Div. 18, sec. 60231.

Management of basins along a stream system must be coordinated. Joint management of two or more basins by a single management unit may often prove convenient.

Within a Groundwater Basin.--Within a single basin, those in a favored position often oppose a basin-wide solution. In West Basin the shortage was felt first near the coast. The coastal fringe of West Basin formed the West Basin Municipal Water District and joined the Metropolitan Water District in 1948. The inland cities of West Basin rejected the move; but after the shortage moved inland, they were forced to seek a supplemental supply, so they joined the West Basin Municipal Water District and were annexed to the Metropolitan Water District.1/

Four cities formed the San Gabriel Valley Municipal Water District to avoid being included in the larger municipal water district (the Upper San Gabriel Valley Municipal Water District). The two districts will be able to independently obtain supplemental supplies, but integrating the management of ground and surface water will eventually depend on cooperation. Unless the two districts can jointly reach a settlement with the Central Basin pumpers in the current suit against all San Gabriel Valley pumpers, this suit will force an adjudication of all groundwater rights in the San Gabriel Valley. Even if rights are adjudicated, management of the basin will depend on cooperation between the two districts to manage the basin either through the existing organization structure or through a replenishment district formed to overlie both municipal water districts. If an agreement with the lower area can be reached, the basin underlying the San Gabriel Valley might be managed without an adjudication. Successful management without an adjudication will require a high level of cooperation between the two municipal water districts.

Should the City of Los Angeles be successful in its suit against all others pumping from the San Fernando Valley, the problem of integrating management will, of course, be eliminated. If rights are adjudicated on the basis of prescription, a replenishment district can be formed, or the basin can be managed through the courts as is presently being done in Raymond Basin. With

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1/ Statement by Carl Fossette in California Legislature, Assembly Interim Committee on Water, op. cit. (Anaheim, 1961), p. 130.

management through the courts, the basin's storage capacity can be utilized to smooth out fluctuations in local supply, and credit for replenishment by individual pumpers can be arranged. However, effective utilization of underground storage to permit the most economical staging of expansions in import facilities will likely require an integration of management beyond that which can be accomplished through the courts.

Coordination of the Entire Stream System.--Conflicts of interest arise from the fact that the effects of overdraft are not felt by all pumpers along a stream system at the same time.[1/] Where the flow from one basin is the supply for another, the consequences of increased pumping from the upper basin fall primarily on the lower. We can expect pumpers in the lower basin to favor either a division of the water between the basins or joint management of both basins. Upstream pumpers, however, are not likely to be enthusiastic about either alternative. Experience in Los Angeles County sheds some light on this problem.

The plight of West Basin: In retrospect, it seems strange that West Basin pumpers did not begin legal action to restrict upstream pumpers at the same time they began the adjudication of rights in West Basin. We must consider, however, that before the investigation of the Referee, the extent to which the recharge of West Basin depends on water levels in Central Basin was not fully known. There was no way of foreseeing the rapid increase in upstream pumping and the resulting fall in groundwater levels in Central Basin. Furthermore, West Basin pumpers knew that a suit to limit upstream pumping would be long, expensive, and possibly unsuccessful. Considering these facts and the urgency of the seawater intrusion problem, West Basin pumpers decided to concentrate on adjudicating rights within the Basin rather than to venture a suit against upstream pumpers.[2/]

Increased upstream pumping and a long period of less than average precipitation resulted in rapidly falling water levels in Central Basin. This created a dilemma for West Basin pumpers who needed to reduce pumpage to prevent seawater intrusion but, because of falling water levels in Central Basin, could not do so without decreasing (or possibly reversing) the flow from Central

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1/ For additional discussion of this problem, see ibid., pp. 129-132.

2/ Interview with Max Bookman, December 4, 1962.

Basin. With unrestricted pumping from the upstream basins, the adjudication of rights within West Basin proved to be of limited value.

Without a reduction in pumping, the confined aquifers underlying 70 percent of Central Basin could not transmit water fast enough to prevent water levels from falling. The Central Basin Water Association requested the Central and West Basin Water Replenishment District to initiate an adjudication of groundwater rights in Central Basin. Thus, the reduction in draft in Central Basin came as a result of problems within Central Basin rather than by the initiative of West Basin pumpers.

The Central Basin vs. the San Gabriel Valley: The basin underlying the San Gabriel Valley is deep, generally unconfined, and drains only through Whittier Narrows. The flow into Central Basin depends on groundwater levels in the San Gabriel Valley. The Central Basin pumpers could protect their interests only by initiating legal action to limit extractions by upstream pumpers.1/ The parties are attempting to avoid the costs of litigation by negotiating an agreement. In these negotiations, the bargaining power of the lower area rests solely on the threat of forcing a reduction in pumping in the upper area if an agreement cannot be reached.

Some readers may have noticed the absence of any reference to conflict between the San Fernando Valley and the coastal plain over the natural yield of the Los Angeles River drainage system. To the writer's knowledge, those pumping from the coastal plain downstream from Los Angeles have never attempted to restrict extractions from the San Fernando Valley. The City of Los Angeles claims a pueblo right to both the surface and underground flow of the Los Angeles River and is attempting to stop others from pumping from the San Fernando Valley. Since prescriptive rights cannot be gained against upstream users, pumpers downstream from Los Angeles are not likely to find a legal basis for

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1/ A similar situation exists on the Santa Ana River. In order to limit diversions of streamflow and groundwater extractions in the upper area, the Orange County Water District has brought suit against the cities of San Bernardino, Redlands, Colton, and Riverside. The first decision of the trial court was favorable to Orange County, but the upper court reversed the decision and remanded the case to the trial court with instructions as to what the judgment should contain. The second judgment of the trial court was also reversed. The upper court again remanded the case to the trial court and gave additional instructions. Alan W. Strong, "Analysis of Orange County Water District v. City of Riverside--No. 4746," Ground Water Problems in California, Report of the Assembly Interim Committee on Water, Vol. 26, No. 4, December, 1962, pp. A-29 to A-31.

demanding an increased supply from the San Fernando Valley even if the present suit over groundwater rights in the San Fernando Valley is decided on the basis of prescription. It appears that except for occasional flood waters very little water from the San Fernando Valley will be available to users downstream from Los Angeles.

Division of water between basins or joint management: The conflicts of interest between basins along a stream system are quite similar to those between pumpers sharing a common basin. The major difference is that actions of those pumping from the same basin are interdependent, while increases in extractions from a downstream basin may or may not (according to the connection between the two) have any effect on the upstream basin. The conflict between basins can be settled either by dividing the local water or by jointly managing the related basins.

Central Basin and West Basin are moving in the direction of joint management. Both are included in the Replenishment District, and both have formed special assessment zones within the Flood Control District. The planned reduction in draft in Central Basin will put the two on an equal basis, except for the difference resulting from the fact that Central Basin is making the same percentage reduction from a later base period. In view of the rather close hydrologic relationships between the two basins, joint management appears to be the most practical.

The hydrologic relationship between the coastal plain and the San Gabriel Valley is one of dependence rather than interdependence. Dividing the stream system's natural yield is solely for the benefit of the coastal plain. Nevertheless, there is an economic interdependence. Assuming that the natural yield is going to be shared, there is a possibility for mutual benefit from integrating the management of the two basins. Storage capacity in the upper basin in excess of that needed by the upper area can be utilized by the lower area. Spreading in the San Gabriel Valley would increase subsequent flows to the coastal plain. During the interim period, San Gabriel Valley pumpers would benefit from the reduced pumping lifts.

If both the San Gabriel Valley and the Upper San Gabriel Valley Municipal Water Districts elect to join the Metropolitan Water District, the groundwater basins of the San Gabriel Valley and the coastal plain can be jointly managed as a single unit. This can be done by expanding the Replenishment District to include the San Gabriel Valley. The formation of such a union would likely

require an adjudication of rights in the San Gabriel Valley and a reduction in pumping comparable to the planned reductions in Central Basin and West Basin. However, in a report for the Upper San Gabriel Valley Municipal Water District, it was concluded that most of the District's supplemental water needs can be supplied more economically by replenishing the groundwater basin than by direct delivery.[1/] The storage and conveyance capacities of the basin are sufficient to permit most, if not all, of the supplemental water to be purchased during periods when water is available at the lower rate normally charged for replenishment use. Therefore, the San Gabriel Valley pumpers are not likely to favor a reduction in pumping comparable to that planned in Central Basin and West Basin, and the Central and West Basin Water Replenishment District is not likely to be expanded to include the San Gabriel Valley.

Even without a single replenishment district overlying the coastal plain and the San Gabriel Valley once the natural yield is divided, it should be possible to arrange for the lower area to use storage space not needed by the upper area.

There are definite conflicts of interest among basins along the San Gabriel drainage system. However, the importance of settling issues without unnecessary litigation and of coordinating the management of the entire system has been recognized. This is exemplified by the fact that one man, Carl Fossette, is the executive secretary of the following organizations:

Central and West Basin Water Replenishment District
Central Basin Municipal Water District
Central Basin Water Association
Upper San Gabriel Valley Municipal Water District
Upper San Gabriel Valley Water Association
West Basin Municipal Water District
West Basin Water Association

Integrating Management Involves Several Simultaneous Changes

To facilitate discussion, questions regarding the establishment of collective control over groundwater extractions were originally separated from other problems of organizational structure. Analysis of alternative ways of controlling draft revealed close interrelations between the method of controlling

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1/ Stetson, Strauss and Dresselhaus, Inc., A Final Report . . . , p. 29.

extractions and the associated decision-making structure. The adjudication of groundwater rights in West Basin was of significant value only after similar action was taken in Central Basin and the two areas launched a joint replenishment program. Economic control over pumping is feasible only when administered by an organization covering at least an entire groundwater basin (perhaps an entire drainage system unless the natural yield is divided among the basins) and capable of coordinating extractions, importation, and replenishment. Moving from a situation where groundwater is a fugitive resource to be captured through use to one where extractions are collectively controlled and the basin is used in conjunction with an imported supply requires several interrelated changes to be made simultaneously.

SUMMARY AND OUTLOOK FOR APPLICATION OF RESULTS

The experience of Los Angeles County has been analyzed in an attempt to (1) identify the basic requirements for the effective utilization of local groundwater basins and water importation facilities, (2) evaluate alternative means of establishing collective control over groundwater extractions, and (3) evaluate alternative organizational structures for integrating the management of ground and surface water in relation to water importation.

The construction of import facilities proved to be only one step in stopping the overdraft of groundwater basins in Los Angeles County. Maintenance of groundwater reserves through increased importation of Colorado River water would have been highly economical for the area as a whole. However, previous to any progress in coordinating their interests, each of the pumpers sharing a common basin realized that purchasing imported water in lieu of pumping groundwater only left more groundwater for the others.[1/] Progress toward efficient joint utilization of local groundwater basins and imported supplies has

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1/ Similar management problems exist for all resources which must be captured through use. These fugitive resources include game, fish, range forage on the public domain before the Taylor Grazing Act, oil, and natural gas as well as groundwater. Individuals acting independently have no economic incentive to conserve these resources; each user realizes that consuming at a slower rate only leaves more to be taken by others. Where the value of the resource exceeds the cost of capturing it, collective control is necessary to prevent rapid and often wasteful depletion. For additional discussion of the management of fugitive resources, see Ciriacy-Wantrup, Resource Conservation . . . , pp. 141-149.

been made only where pumping rights have been quantitatively defined or group action has been taken to purchase water for replenishment purposes.

When used in conjunction with imported supplies, groundwater basins have great potential for supplying seasonal peaks in demand, for smoothing out seasonal and cyclical fluctuations in local supply, and for making possible an economical staging of expansions in import capacity. As water use increases in the Los Angeles area, local groundwater basins are becoming relatively less important as natural sources and more important as reservoirs. This storage space can be effectively utilized only if the management of ground and surface water resources are closely integrated.

Some form of control over groundwater extractions is essential for integrating ground and surface water management. Adjudication of pumping rights and collective control through economic incentives to individual pumpers have been discussed in considerable detail. Only the major conclusions will be summarized at this point.

Where importation is expensive, as it is in Los Angeles County, the assessment of groundwater extractions appears to be essential for controlling draft through economic incentives. Pricing imported water competitive with the variable costs of pumping groundwater would encourage water use in excess of that commensurate with importation cost, and the portion of water cost which would have to be met through taxation would be too large for political acceptance.

Draft control through economic incentives cannot be effective if pumpers anticipate a future adjudication based on prescription. The rights of those using imported water in lieu of pumping from an overdrawn basin are not adequately protected under existing legislation. An amendment to the Water Replenishment District Act could allow a choice at the time of formation between the existing provisions (which give a district power to initiate an adjudication and require that adjudicated shares of natural safe yield be exempted from replenishment assessments in the event of the adjudication of all or substantially all of the rights to the basin's natural safe yield) and an alternative plan which would not give the district power to initiate an adjudication of rights within the district and would not provide for exempting any extractions from the replenishment assessment. In a replenishment district adopting the latter alternative, there would be no incentive to use groundwater to build up a prescriptive base.

Thus far, long and expensive litigation has been necessary to adjudicate groundwater rights. Although the Raymond Basin case was eventually settled despite the persistent opposition of one party, progress has been extremely slow in the absence of agreements among most of the large pumpers. Agreement cannot be expected in every case. With the City of Los Angeles claiming a first right to all the natural yield of the San Fernando Valley, there is no basis for an agreement. Those pumping from a basin which is replenished by drainage from an upstream basin cannot protect their share of the natural yield without an effective procedure for adjudicating rights. The existence of a more effective adjudication procedure would, moreover, give downstream pumpers a stronger basis for negotiating an agreement with upstream pumpers.

Based on the present study, a few recommendations for improving adjudication procedure can be made. The number of parties can be greatly reduced without significantly affecting the results by excluding those pumping small quantities (say, less than 10 acre-feet per year). The problem of identifying parties can be solved by amending the Water Recordation Act to require reports of extractions from all those pumping enough to be included in an adjudication. To permit interim control over extractions when an agreement cannot be reached, the Water Code could be amended to allow unvalidated reports filed under the Water Recordation Act to be used in a preliminary judgment, provided supplemental water is available and provisions are made for injured parties to be reimbursed after a final judgment based on validated records is made.

With regard to convenience in integrating management and to efficiency of resource allocation, there appears to be no significant difference between management with adjudication and management through economic control over extractions. The difference in the distribution of benefits from the natural yield of the underlying basin is large if some parties are rapidly increasing water use and others are not.

In the Raymond Basin, considerable progress in coordinating the management of ground and surface water has been made without formation of an overlying district to manage the Basin. However, in most cases, an overlying district will probably be essential for fully integrated management even where rights have been adjudicated. A public district (overlying an entire basin) is needed with broad powers for purchasing imported water for replenishment, coordinating the management of related basins, and coordinating the management of the Basin with expansions in import facilities.

Successful integration of management without an adjudication of rights is entirely dependent on the formation of an overlying district with extremely broad powers. Legislative authorization for such a district could be provided by the previously recommended amendment to the existing Water Replenishment District Act. Since broad powers are essential for a coordinating agency, constant vigilance will be required to avoid unnecessary duplication of existing facilities and services.

Areas beginning water importation in the future will probably encounter management problems similar to those which have plagued southern California for almost 20 years. Much can be learned by studying past experience in southern California.

Considering the time required to make institutional changes, those planning to import water under the State Water Plan should immediately begin making the institutional modifications needed to integrate the management of local groundwater basins with the imported supply. Arousing public interest previous to the actual existence of the problem will not be easy. Recall that the need for integrated management was recognized in southern California before the first deliveries of Colorado River water. It is imperative that community leaders inform the public of the advantages of jointly utilizing local groundwater basins and imported supplies. The length of time required for making institutional changes and the potential loss if the changes are not made by the time the imported water becomes available should be stressed. Examples from past experience in Los Angeles and Orange Counties will be helpful.

Meanwhile, new problems are developing in southern California even before the basic problems of common use have been solved in some basins. The demand for water, the distance to new sources, and the cost per unit of additional imports continue to increase. The Supreme Court decision in favor of Arizona jeopardizes the supply from the Colorado River and intensifies the importance of making full use of this supply while still available.

As the demand for water grows, more distant sources must be utilized, and it becomes increasingly essential that the management of imported supplies and local groundwater basins be closely integrated.

For at least a few years following completion of the proposed aqueduct from northern California, import capacity will likely exceed that needed for current use. The variable cost per unit of importing this water will not be low, but it will undoubtedly be considerably less than the total cost per unit of importing with some future expansion of facilities. A great opportunity will be lost if groundwater levels are not built up while import capacity is available.